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Designed And Analysed Open Loop Hi-Bridge Resonant Soft Switched Boost Converter

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Abstract

In this thesis a new type of soft-switching DC-DC boost converter is proposed instead of hard–switching. In conventional converter there is some loss across switch when it turns ON to OFF and OFF to ON and then so efficiency of the device is limber down.

This proposed converter uses a soft-switching method containing a resonant circuit; circuit contains a resonant inductor, two resonant capacitors, auxiliary switch, and diodes. In this proposed converter we apply the soft switching technique on both the switches (main and auxiliary). This will also increase the converter efficiency. The efficiency of the converter is improved only by reducing the switching losses as putting some stress or tension on the converter component by using HI-Bridge auxiliary resonant circuit.

Proposed converter has been simulated in MATLAB Simulink software and the performance of the boost converter is verified through the theoretical analysis and simulation and experimental result of the proposed converter.

I) Introduction

In conventional device we use passive component (inductor, capacitor etc.) they make our device bulky and costly. When we want more power from these devices they become more bulky and costly. So we reduced or overcome these problems by increasing the switching frequency of the device for achieving the same power from small device.

but we know there are some loss across switch when it turns On to Off and Off to On and when we increase the switching frequency of the device to achieve the same power as in bulky device the power loss is more across switch and also efficiency of the device is go down.[5][6]

But at another side high switching frequency can substantially improve transient performance; control bandwidth and also high frequency allow the use of air core magnetic and paving the way towards fully integrated power converters. Thus we realized many use full benefits by operating the device at increases switching frequency if and only if when we control the loss across switch and control the efficiency of the system.

We use several switching devices in power converter to convert input power into desire power (ac to dc , dc to ac , dc to dc etc) the switching devices are use to turn on and turn off the device or entire load current at high di/dt . The device operates on high di/dt and also face high voltage stresses across them. Due to these two effects in the switching device power loss is increases and when we want to reduced the size and weight of the power converter, we need to increase the switching frequency of the power converter. And this thing is further aggravated switching losses and high voltage stresses on the device. Also another problem will face high di/dt and high dv/dt due to rapid turn in off the device [3][7]

These problems can be minimised when each switch of the device turn OFF to ON and ON to OFF at one of the voltage or current are zero at the instant of switching. This also called soft switching and the converter circuit which permit the zero voltage and zero current switching are called resonant converter,[2] mostly we use L-C resonance circuit in power converter for resonant purpose. With the help of this resonant technique we reduced the losses across switch during turn ON and OFF. So power loss is negotiating.

In this paper, also some simulation results are presented for a 30-kHz prototype boost and high boost converter both using MOSFET. Also experimental results are presented to verify the operational principle of the proposed circuit.

II) Types of DC-DC converters [4][6][8]

We will divide dc-dc converters into two main types:
A) Hard-switching DC-DC converters.
B) Soft-switching DC-DC converters.

A) Hard switching topologies:

Converters which are based on conventional switching are called as hard switching converter. During Turn ON period the voltage across the switch tends to increase and the current tends to decrease, which results in some switching losses. Similarly during turn OFF period the voltage tends to decrease and the current tends to increase across the switch. Again we see there are some switching losses are occurring.

During switching processes, simultaneously the power device stand at high voltage and high current, resulting in more switching losses and stresses are present.

B) Soft switching topologies:

Soft switching techniques can reduce switching losses and electromagnetic interference by putting some tension on the devices. When a current or voltage is zero during the turning ON or OFF period, and then the product of the voltage and the current becomes zero, leading to zero power loss. Therefore the switching loss can be removed and the device can operate at high switching frequency. Dimensions and weight of the device is reduced since it does not require the heat sink [1][4][5].

III) Analysis of the soft switching boost converter [1][2]

In this research study a new soft switching resonant DC-DC boost converter with an auxiliary switch is introduced. Resonant circuit use in this converter for provide the resonance to the main switch, this auxiliary resonant circuit or switch consist resonant inductor L_r , resonant capacitors C_{r1} and C_{r2} , two ideal diode and one auxiliary switch S_a (MOSFET). These resonant components make a suitable resonant path for the main switch for getting a soft switching means ZVS and ZCS conditions.

A) Operation of the proposed soft switching boost converter.

Introducing proposed topology the generation of switching losses are avoided by forcing voltage or current to Zero during switching. The efficiency is improved due to reduction in switching losses, [1], [3].

The circuit scheme of new proposed soft switching boost converter is shown in Fig. 1 The main switch (S_M) and the auxiliary switch (S_A) of the proposed converter circuit enable soft switching through HI-bridge block.

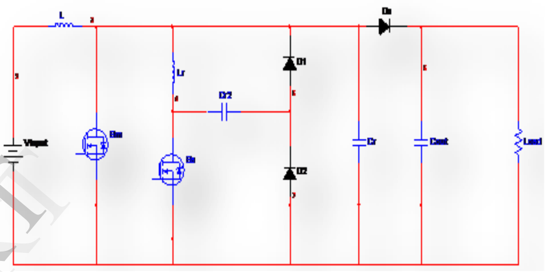

Fig 1 Proposed soft switching converter

In this part take some assumption to easily or simply understand the converter circuit, steady state analysis during one switching cycle.

1). All switching device and passive element are taken ideal

2). Input or source (V_{in}) voltage is taking constant.

3). The output or load voltage (V_{out}) also taking constant.

4). All diode reverse recovery time are ignored.

Here For simple calculation take nine (A to I) Operation stages in a single switching cycle.

Stage A(to<t<t1)

At initial stage of operation take both the switch are open or in OFF state. So at stage A current flow through the source and then main inductor L and than reach the load through main diode. Due to current pass through the main inductor the energy is accumulated in the inductor is transferred to the load.

During this period main switch, auxiliary and the resonant current is zero and the resonant capacitor voltage is charged up to the output voltage.

Applying KVL $V_l(t) = Vin - Vo$ (1)

$$il(t) = \frac{1}{L}\int Vldt \quad (2)$$

$$il(t) = \frac{Vinput - Vout}{L}(t - to) + I(t9) \quad (3)$$

$$i_{Lr}(t) = 0, Vcr(t) = Vout, Vcr_2(t) = 0 \quad (4)$$

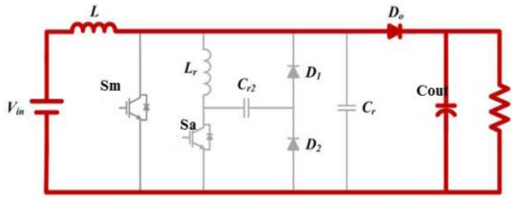

Fig 2 stage A of the proposed soft switching converter

Stage B (t_1<t<t_2)

At this stage firstly applies the gate pulse to auxiliary switch. After turn ON, switch is conducting the resonant inductor current ready to increase smoothly from initial. Stage B is complete at that moment where the resonant inductor current equal to the main inductor current at t_2. Also at that time resonant inductor voltage is equal to the output voltage.

$$I_lr(t) = \frac{Vout(t-t1)}{Lr} \quad (5)$$

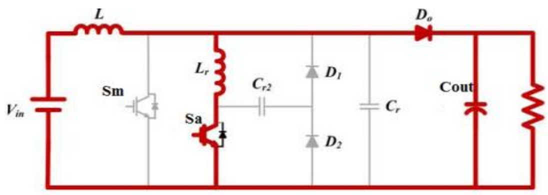

Fig 3 stage B of the proposed soft switching converter

Stage C (t_2<t<t_3)

In this stage our resonant technique is work means they both resonant component (resonant inductor, resonant capacitor) start their resonance. And energy stored in resonant capacitor is discharged through the resonant inductor, the path shown in figure. After completion the resonant process the resonant capacitor voltage is fully discharge and the resonant capacitor voltage is becomes zero after this stage C is complete. During this stage the resonant impedance and angular frequency are given by Zr and Wr.[1]

$$Vcr(t) = Vout \times \cos w_r(t-t_2) \quad (6)$$

$$Zr = \sqrt{\frac{Lr}{Cr}}, \quad Wr = \sqrt{\frac{1}{Lr \times Cr}} \quad (7)$$

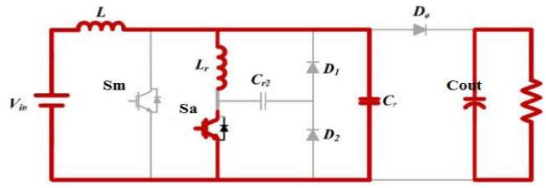

Fig 4 stage C of the proposed soft switching converter

Stage D (t_3<t<t_4)

In this stage where the resonant capacitor voltage is zero, body diode of the main switch is conducting automatically due to natural process. So at that moment we apply the gate pulse to main switch where body diode of the main switch is ON the voltage across the main switch is going zero and at that time we achieve the condition of zero voltage switching (ZVS). At the initial point of this stage we assume

$$Vcr(t) = 0, Vcr_2(t) = 0 \quad (8)$$

$$i_L(t) = i_{min} + \frac{Vin}{L}(t-t_3) \quad (9)$$

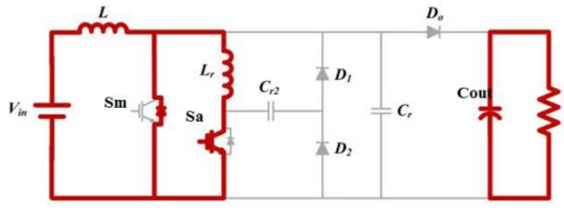

Fig 5 stage D of the proposed soft switching converter

Stage E (t_4<t<t_5)

Stage E begins when auxiliary switch is turned is off. In this stage another resonant element or component combination (resonant inductor and resonant capacitor Cr_2) start resonance. This stage is complete when the resonant capacitor Cr2 has been fully so due to this the resonant inductor current is going zero.

Resonant impedance and angular frequency are present by Za and Wa.[1]

$$iLr(t) = iLr(t_3)\ Cos\omega_a\,(t-t_4) \qquad (10)$$

$$w_a = \frac{1}{\sqrt{Lr \times Cr2}},\ Za = \sqrt{\frac{Lr}{Cr2}} \qquad (11)$$

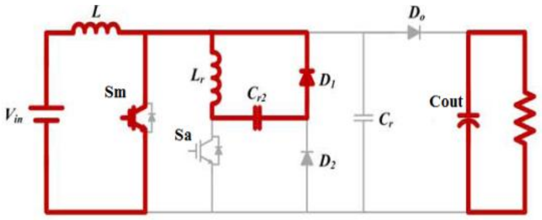

Fig 6 stage E of the proposed soft switching converter

Stage F (t_5<t<t_6)

At the last of the mode E the capacitor Cr2 is fully charged and auxiliary switch is in off state so now at stage F the resonant capacitor Cr2 is try to discharge through resonant inductor but the direction of the current is reverse and that instant stage F is start. In this stage the reverse resonance current flow through the inductor Lr then through the main switch and then D_2 diode.

Now when the resonance capacitor Cr2 is fully discharged voltage of this is zero and the resonance between Lr and Cr2 is complete. We examine the capacitor voltage charged and discharged during this stage and in just previous stage. So this can be realized by the equation

$$Vcr_2\,(t) = Zai_{Lr}\,(t3)\ \sin wa\,(t-t_4) \qquad (12)$$

$$Vcr_2\,(t_5) = Zai_{Lr}\,, \quad V_{Cr2}(t_6) = 0 \qquad (13)$$

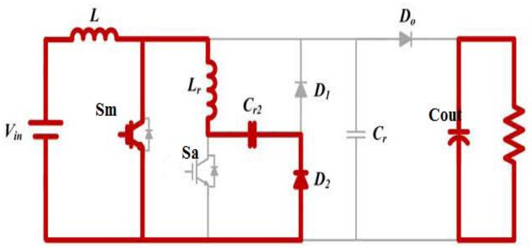

Fig 7 stage F of the proposed soft switching converter

Stage G (t_6<t<t_7)

At the end of the stage F the resonant capacitor C_{r2} voltage becomes zero. That means resonant capacitor Cr2 behave as a short circuit and energy source for the reverse current is closed. Now from the property of the inductor (oppose the change in current) the body diode of the auxiliary switch is turned ON. The reverse current path in this stage is through body diode of auxiliary switch, main switch and resonant inductor, this path also called as freewheeling path. Now when the main switch is turned off by the pulse width modulation at that point this stage is complete.

In that stage the main inductor current is

$$i_L(t) = I_{min} + \frac{Vin}{L}\,(t-t_3) \qquad (14)$$

And the auxiliary inductor current (reverse current)

$$i_Lr(t_7) = -i_Lr(t_3) \qquad (15)$$

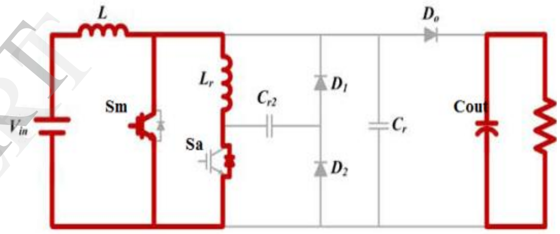

Fig 8 stage G of the proposed soft switching converter

Stage H (t_7<t<t_8)

This stage begins when the main switch is turned OFF under soft switching or zero–voltage condition. Circuit connection of this stage shown in figure (13) and we conclude from the circuit charging current of the resonant capacitor Cr is sum of the two inductors current. This stage is completed when the output voltage is equals to the resonant capacitor (Cr) voltage. Resonant inductor current shown in the equation (17)

$$i_Lr(t) = i_L(t_7) - \{i_L(t_7) + i_Lr(t_3)\}\ Cosw_rt \qquad (16)$$

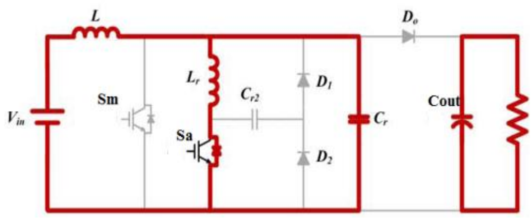

Fig 9 stage H of the proposed soft switching converter

Stage I (t_8<t<t_9)

In stage H the resonant capacitor Cr has been fully charged and the main diode voltage is zero. In stage I the main diode is turned Off to ON at the zero voltage condition. And the resonant inductor current is reducing linearly towards zero. After the resonant inductor current getting exacts zero value, this stage is complete. And then after one switching cycle is complete and next one is start. In this stage [1]

$$iL(t) = iL(t7) - \frac{Vout - Vinput}{L} \qquad (17)$$

$$iLr(t) = -iLr(t3) + \frac{Vout}{Lr} t \qquad (18)$$

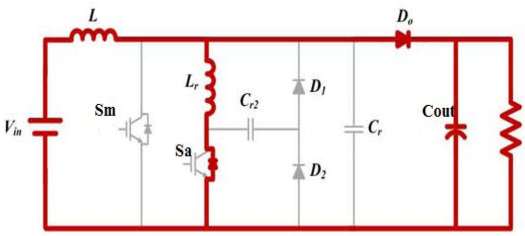

Fig 10 stage I of the proposed soft switching converter

B) Key waveforms of the operation modes

This figure (11) shows the period (time) wise change in parameter value at different-different stages.

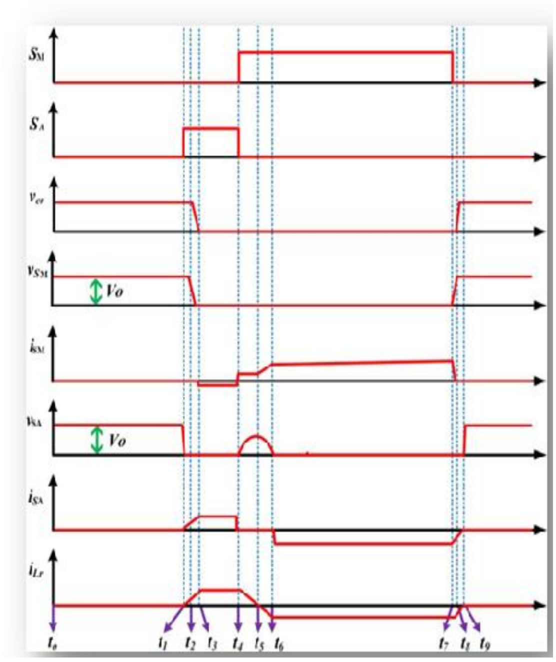

Fig 11 key waveforms of the operation modes in the proposed converter, [1]

IV) Simulation studies:

Simulation studies of the proposed DC-DC boost converter are under taken.

The proposed boost converter with additional HI-Bridge resonant circuit is simulated in MATLAB-Simulink software. The values of the parameters for the circuit are given below:

Input voltage (Vinput) = 120 - 180 V
Switching Frequency (fs) = 30 KHz
Main Inductor (Lmain) = 560 µH
Resonant Inductor (Lr) = 20 µH
Resonant Capacitor (Cr2) = 30 nF
Resonant Capacitor (Cr) = 3.3 nF
Output voltage (Vout) = 350 – 520 V

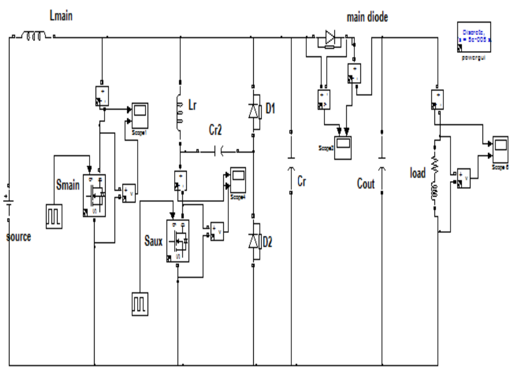

Fig 12 simulated scheme of the HI bridge boost converter [1]

This figure (12) shows the simulated scheme of the HI-Bridge boost converter circuit.

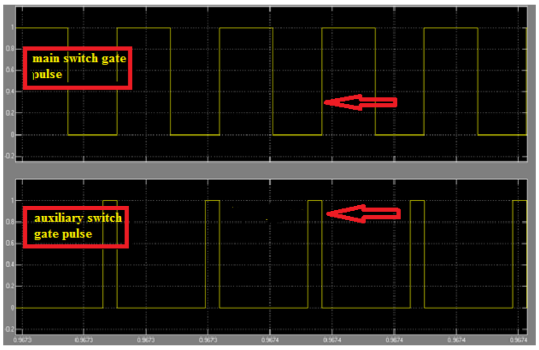

Fig 13 Gate signal for the main and auxiliary switch

This figure (13) shows the turn ON and delay time of both the switches (main and auxiliary).

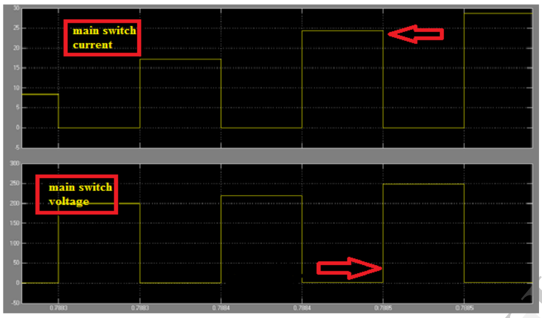

Fig 14 Simulation waveforms of the main switch.

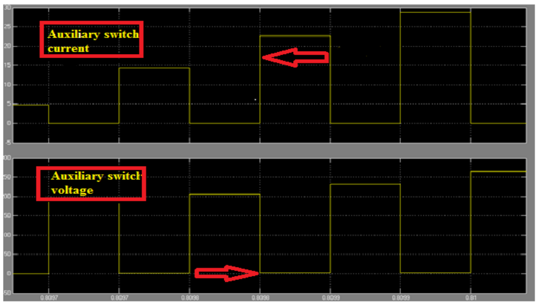

Fig 15 Simulation waveforms of the auxiliary switch.

These figures (13, 14) shows the voltage and current waveform of the main and auxiliary switch simultaneously, and here from the figure easily conclude that our main and auxiliary both switch getting the condition of soft switching.

(There is no overlapping between current and voltage of both the switches)

V) Experimental proposed converter with result

A) Description of the proposed high boost converter circuit:

In this proposed High Boost converter we use two resonant circuits in parallel with the main switch.

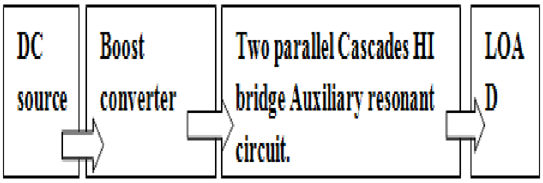

Fig 16 Block diagram representation of high boost converter

The voltage gain of the soft switching converter can be increased up to a certain level by using two and more parallel connected HI-bridges (resonant circuit) without affecting the complexity of the circuit. The auxiliary resonant circuit is modified to cascaded parallel bridge. In this paper use two HI-Bridges connected in parallel manner for more boost voltage and current and so efficiency of the converter becomes better.

B) About the high-boost converter circuit:

Here we show the circuit configuration of the High-Boost soft switching DC-DC converter.

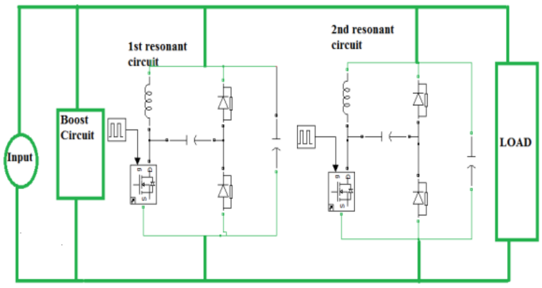

Fig.17 Arrangement of the High-Boost converter circuit

Easily seen by the figure, our proposed HI-Bridge High-Boost circuit having a two resonant circuit (1^{st} resonant circuit and 2^{nd} resonant circuit) with the help of these two circuits we enhance the output voltage and efficiency of the converter also.

C) Compared data between boost converter and high boost converter:

Table 1 Comparison data between boost and high boost converter.

INPUT	OUTPUT OF BOOST CONVERTER		OUTPUT OF HIGH-BOOST CONVERTER	
VOLTAGE	VOLTAGE	CURRENT	VOLTAGE	CURRENT
180 volt	520 volt	2.16 amp	692 volt	2.88 amp
150 volt	435 volt	1.8 amp	576 volt	2.4 amp
120 volt	350 volt	1.45 amp	461 volt	1.92 amp

Table1 shows the compared data of the Boost and high boost converter, from the table we seen that at same input voltage we get the higher output voltage in proposed High-Boost converter than the Boost converter. Also get the better efficiency.

Conclusion:

In this paper, a new soft-switching open loop High-Boost converter using a resonant circuit has been discussed which uses an auxiliary switch with resonant circuit. This paper has proposed a high efficiency soft switching High-Boost converter which uses a two resonant circuit and an auxiliary switch in parallel, compared with the single one, which has higher efficiency and more voltage boost effect. The switching losses are minimized by soft switching and efficiency of the boost converter is improved because the auxiliary and main switch is turned ON and OFF by the zero voltage (ZVS) and zero current (ZCS) switching.

The operation principles and theoretical analysis of the proposed High-Boost converter have been confirmed by simulation and a comparison data. The results are found to agree with the theoretical analysis, presented in this paper.

REFERENCES

[1] J.S. Yu, S.R. Park, Y.C. Jung and C.Y. Won, S.H. Park, "Analysis and design of a soft switching boost converter with an HI-bridge auxiliary resonant circuit," IEEE Trans. On Power Electronics, pp. 2142-2149, vol. 25, no. 8, August 2010.

[2] C.-S. Leu, Y. Jiang, F. C. Y. Lee and G. Hua, "Novel zero-voltage transition PWM converters," *IEEE Trans. Power Electron.*, pp. 213–219, vol. 9, no. 2, Mar. 1994..

[3] A. F. Bakan and H. Bodur, "A new ZVT-ZCT-PWM DC-DC converter," IEEE Trans. Power Electron., pp. 676–684, vol. 19, no. 3, May 2004.

[4]www.ee.cityu.edu.hk/~shc/Chapter7.doc. Hard switching and Soft Switching Techniques.

[5] Brigitte Hauke, "Basic Calculation of a Boost Converter's Power" Stage Application Report, SLVA372B–November 2009–Revised July 2010

[6] G. Joos, P. K. Jain, and N. Jain, "A zero voltage transition boost converter employing a soft switching auxiliary circuit with reduced conduction losses," IEEE Trans. Power Electron, vol. 19, no. 1, pp. 130–139, Jan. 2004.

[7] B.R. Hou, B.R. Lin, "Analysis of a zero voltage switching DC/DC converter without output inductor," IET Trans. Power Electron., vol. 5, no. 6, 790 – 800, July 2012.

[8] Dr. P.S.Bhimbra," power electronics," KHANNA PUBLISHERS, Nai sarak, NEW DELHI-110006.