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VOLTAGE GAIN OF A DC-DC LLC TYPE RESONANT CONVERTER

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***Abstract*— Voltage gain for dc-dc LLC type resonant converter is typically appropriate for high power applications. The mechanism and equilibrium of resonant converters are vital concerns in power electronics. The controller scheme and constancy exploration for these converters are built on the true averaged model. Therefore, using large signal and non-averaged models are essential for controller design and stability . The dc–dc LLC type resonant converters are sensibly switched affine systems with exact switching law. The planned controller is based on the switched performance of the converter and the origin of piecewise affine method. Additionally, it has switched inside and proportional-integral (PI) external regulator loops does not require a modulator. The projected controller has a smaller amount density when compared to other advised controllers. The simulation outcome demonstrations the efficiency of the proposed method. The planned method is systematically simulated using MATLAB/SIMULINK.**

Key words— PWM

I. INTRODUCTION

In modern days, using high-frequency power converters is probable in various applications. The switching losses and electromagnetic interferences are main disputes widespread by these converters. Resonant converters can astonish these limitations by using zero current and/or voltage switching. Owing to the large ac eccentricities in currents and voltages of the resonant cistern, the linearized model of the resonant converters has widely large forming error. This incidence creates the control of resonant converters extra complex than pulse width modulation (PWM) converters.

These outcomes are used to train these three design difficulties. First, the variance of peak fundamental traumas with the choice of worst-case operating point and some approaches concerning the choice of transformer turns ratio and tank representative impedance . Additional, the properties of eccentricities in participation line voltage and output load current are plotted using the converter production landscapes. LLC resonant converter displays abundant subordinate switching loss connected with PWM converter as shown in earlier part. Associate with PWM converter, the primary switching loss is abbreviated by more than 50%. Secondary diode commutate certainly so there is no opposite recovery problem.

The nonlinear investigation and supervisor design of the resonant converter were existing in [1] and [2]. The nonlinear permanence examination of the resonant converters has been discovered in [3]. Yet, the strength exploration and controller design of nonlinear dynamics are complex and there is no logical method for constancy analysis of these types of converters in general. The piecewise affine (PWA) or piecewise linear (PWL) estimate of nonlinear averaged model are solutions for this problem.

These methods have been useful to nonlinear be around model of dc–dc PWM rectifiers [5], and quasi-resonant converters [6]. Then of the great ac differences of resonant tank variables, using these means on non-averaged model of the converters [4], control issue correction resonant converters is not acceptable. A crossbreed evenness approach was untaken in [7] which remain about perfect of the converter and insensitivity based control. The robust presentation and stability are the bounds of this paper. The switched control of a three-phase PWM rectifier was obtainable in [8].

Greatest state response control of PWM dc–dc converters is accessible in [9] which assurance the area of stability. The large signal stability of the buck converter was assumed in [10] which provide a fixed frequency hysteresis controller by using Overturned method and Break model. This method uses the be around and describes the region of stability. In [11], the diverse control of *LLC* resonant inverter is available founded on frequency and duty is based on the series switch for steady state and fleeting replies, singly. In this paper, a new class of hybrid systems is in this paper, a new class of hybrid schemes is offered for mixture modelling and control of resonant converters. Meanwhile the accessible class is similar to PWA systems and it is resulting straight from switched model of converter, it is called direct PWA (DPWA). The DPWA modelling of the resonant converters was chief available by the writers in [12]

In this tabloid, using DPWA modeming method, the shut ring durability survey, the minimum stage display of control system, and controller strategy for a dc–dc series resonant converter is empty. The hybrid control of a dc–dc resonant converter is attained by an adaptive switching plan which is presented in paper[24]. This trick covers of two dissimilar inner and outer control loops that are swapped and PI control loops, separately.

The inner loop panels the transient response and the outer loop orders the steady-state response. The internal control loop has a big bandwidth that it is close to the switching frequency. The outer control loop has a lesser bandwidth that it is around the inverse of output clean time constant. On the extra needle, the outer loop publicizes the conditions of the inner loop. The linked closed loop constancy examination is also lectured, and, also, a switched switch plan is nearby for regulator of DPWA model of converter which can overwhelmed the main borders of the conservative controller angles.

The available method has modest construction does not require a modulator and is applied by simple analogy circuits. The inference of tank capacitor voltage is done by using integrator and current classifying pathways.

The chief contributions of this paper are as follows: 1) a new hybrid control plan is existing which does not need a modulator, 2) the control plan for the hybrid model of the LCL type resonant converter is proclaimed and the closed loop system is connected in DPWA form, 3) the closed loop and zip dynamic stability analysis of the optional technique is vacant, 4) the future technique uses the progressive mock-ups of hybrid control schemes but they could be realized by humble similarity paths.

II. SWITCHED SCHEMES

In this method, two kinds of swapped organizations are familiar which will be second-hand in the unfilled modelling method.

A. PWA Models

A faultless of continuous cross scheme in which many prospectuses of cross systems are extended for dissimilar uses. Switching among subsystems may be free or forced. A well-known class of hybrid systems is the lesson of piecewise affine (PWA) systems which can be industrial for many applications. The stability study and supervisor project of PWA organizations have been careful and the precise boom of a PWA system is

$$\dot{x} = A(x) + B(u) + b\ ,$$
$$y = C(x)$$

B. DPWA Models

The DPWA is subsequent from postponement of conservative PWA into switched systems. The precise picture of this class is

$$\dot{x} = A(x) + b$$
$$y = C(x)$$

DPWA systems are good for demonstrating of power electronic converters such as resonant converters.

III. BLOCK DIAGRAM DESCRIPTION

A. LCL type Resonant Converter

An LCL-type resonant dc/dc converter with a capacitive production sieve is established in two phases. In the first high-frequency ac phase, all ac signals are rotten into two orthogonal vectors in a synchronous turning d–q frame using multi-frequency modeling.

In the additional dc stage, all dc numbers are considered by their average standards with average state-space presentation. LLC resonant converter with hybrid full bridge structure is used to achieve broader voltage gain variety. A two-stage model is then shaped by pays of a non-linear link. By bring into line the transformer voltage on the d-axis, the nonlinear relation can be eradicated, and the whole converter can be showed by a single set of linear state-space equations.

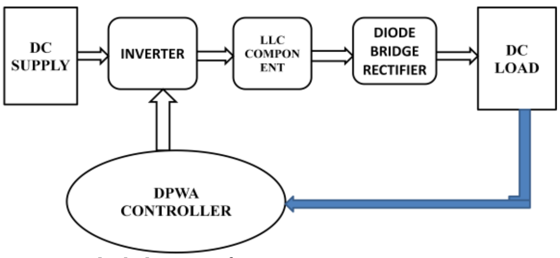

Fig. 1 .Block diagram of DC–DC LLC type series resonant converter.

Also, a feedback control preparation can be formed according to the steady-state answers. There is a phase-shift among the two inverter legs, which is limited to switch the production voltage at dissimilar load level Thus, the HF bond inverter output power is a quasi-square wave. The series resonant frequency $\omega r = 1/\sqrt{LsCs}$ defined by the LCL tank is frequently intended to be quite close to the switching frequency ωs.

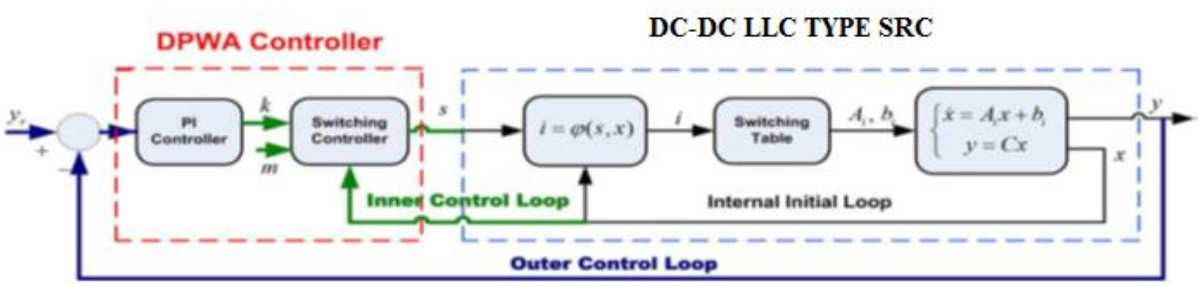

Fig. 2 .Block diagram of DPWA CONTROLLER of DC–DC LLC type series resonant converter.

IV. DPWA CONTROLLER OF LCL TYPE DC-DC SRC

The approach is based on DPWA model which is characterized by following description

A.Adaptive Switched fleeting command and is a switched controller. The contributions of *Controller: DPWA Controller:* The wished-for controller can be demonstrated as a DPWA system and it is predestined as DPWA organizer. The block-diagram of the projected control plan is revealed in Fig. 2. It conceals two altered control loops; the internal and the external loops. The internal control loop has a big bandwidth that controls the switched controller are public variables *x*, dc counterbalance of switching surface *m*, and the slope of switching surface image on $x1 - x2$ plane *k*, and the output of the swapped controller is the logic input *s*. The outer control loop has slight bandwidth that controls the steady-state law and is a PI controller which alters the hill of switching surface image on $x1 - x2$ plane of the inner control loop.

B. Closed Loop Stability Analysis

The closed loop faithfulness study of the wished-for switch system is a serious problematic which is spoke by the next statement.

Theorem 1: Consider the hyper plane DPWA system
$\dot{x} = Aix + bi, x \in \Omega i$
$y = Cx$

$$\Omega_i = \bigcap_{j=1}^{p_i} \{ x \in R^n$$

If one can detection a answer for the subsequent LMIs then the nothing active arrangements is usually stable and the control system is least phase

C. Zero Dynamics of Exact System

In this piece, the constancy study of the zero dynamics for dc–dc LLC type SRC is accessible.

TABLE-1
PARAMETERS OF DC–DC SERIES RESONANT CONVERTER

Symbol	Parameter	Value
C	tank capacitor	$10.6\ \mu F$
L	tank inductor	$10.6\ \mu H$
C_f	output capacitor	$2600 \mu F$
V_g	input voltage	$48V$
V_o	output voltage	$75\ V$
ω_s	angular switching frequency	$100kHz$
ω_r	angular resonant frequency	$54kHz$
R	output resistance	6Ω
V_f	forward voltage of diodes	1.25
r_{Loss}	the sum effect of the inductor resistance and the capacitor series resistance	0.76Ω

The zero altering features is sure to be the internal subtleties of the system when the system output is kept at nothing by the input. The zero changing features are a important object of a nonlinear system, which does not pivot on on the controller or the wanted arcs [17]. The least phase response is a functional point for regulator schemes. For learning the lowest chapter mouth of control arrangement, one essential discover the fidelity of the zero changing aspects. The zero dynamic stability check-up of power electronic converters are travelled in [18]

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V.CIRCUIT DIAGRAM OF LLC RESONANT CONVERTER

The circuit diagram of an HF-isolated LCL-type resonant dc/dc converter is accessible. The contribution dc voltage vs. is transformed into an HF ac voltage by earnings of an HF full-bridge inverter. All shifts are occupied with a fixed incidence. The two changes in each inverter leg are worked otherwise with a duty cycle slightly lower than 50%.

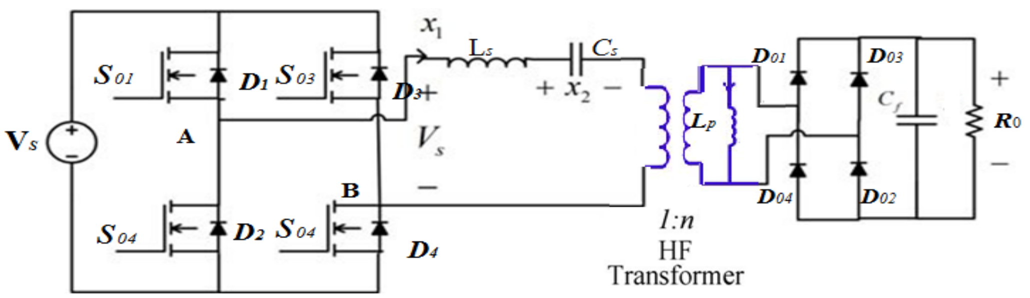
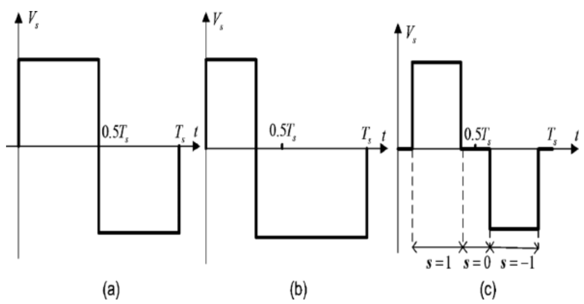


Fig.3. Circuit diagram of DC-DC LLC type resonant converter



The HF modernizer voltage is a square wave due to the belief of a large capacitive output filter. The similar inductor current is a triangular , which is obliging to spread the ZVS (zero-voltage switching) operation range as the cargo contrasts. The resulted converter current is rectified to dc output current over the HF diode

Fig. 4. Waveform of *Vs* for er for different control strategies: (a) frequency,(b) asymmetrical duty cycle, (c) symmetrical duty cycle

VI OPERATING PRINCIPLE

The rudimentary pathway diagram (*LLC*-type) SRC with a capacitive manufacture filter is exposed in

The inductor *L is* placed on the secondary side of the HF modifier so that the charming inductance can be used as part of the similar inductor, and the seepage inductance of the HF modifier can be used profitably as share of the sequence resonant inductor *Ls* .The externally connected. Inductor *LP* is the part of the series resonant inductor *Ls*. *LP* is the consistent connected subsequent value of the inductance Waveform across the output terminals AB of the inverter exposed.

A. Modes of Operation

For an expected switching frequency, answerable on the standards of the machines, load current, supply voltage, and pulse width δ, the converter

may function either in CCM or in DCM with lagging or leading PF. The mode CCM/DCM is utter founded on the present input to the rectifier converter output voltage diagonally the terminals

AB includes a zero voltage interval. The resonant converter has five modes of procedure in continous conduction mode. The resonant current waveform has five intervals in CCM. Employed of the converter with minimum input voltage in CCM and with all-out input voltage in DCM for an arbitrary pulse width angle δ .

i) CCM (continous conduction mode)

Interval 1 (***D*1**, ***D2ON***)
The gating signals for the switches *S0*3 and *S0*4 are separate composed at the end of the previous interval (Interval 5), while switches *S*1 and *S*2 obtain the gating signals at the same time.

Meanwhile the tank circuit current cannot change abruptly; *D*1 and *D*2 come into transmission, subsequent in the voltage V_{AB} to alteration its division to −*Vs*. The output rectifier diodes *Do*3 and *Do*4 are leading, if the load power.

Interval 2 (***S0*1**, ***S02ON***)
When the resonant current originates to zero and becomes negative, *D*1 and *D*2 turn off and switches *S0*1 and *S0*2 turn on with ZVS resounding the resonant current.

Interval 3 (***S0*1**, ***D3ON*)**
The gating signal for the switch *S0*1 is nonstop from the previous interval (Interval 2), while the gating signal for *S0*2 is removed, turning off *S0*2. Temporarily the current done the booming circuit cannot change closely, diode *D*3 twitches conducting. Hence, the current glides finished the path *S0*1–tank circuit–*D*3 – *S0*1, consequential in a zero voltage interval in V_{AB}. The output rectifier diodes *Do*3 and *Do*4 last to conduct, while the load is full by the energy stored in the tank circuit essentials.

Interval 4 (***D*3**, ***D4ON***)
The switch *S0*1 stops showing since its gating signal is uncomplicated, subsequent in the transmission of *D*4. Thus, the current flows done the path *D*3 − *Vs* − *D*4–tank circuit–*D*3, VAB = +*Vs*. The making rectifier diodes *Do*1 and *Do*2 are foremost, providing the load power.

Interval 5 (***S0*3**, ***S04ON***)
At the end of interval 4, the tank circuit current At the end of interval 4, the tank circuit current negative to positive, resulting in the turnoff of *D*3 and *D*4. *S0*3 and *S0*4 turn on with ZVS as they previously have the gating signals

VII. SIMULATION DIAGRAM AND RESULTS

A. SIMULATION RESULTS

A dc–dc LLC type SRC is replicated for validation of the deliberate way it is thoughtful to work above resonance frequency. The main transient riders and lively response for load and line presiding. If the recitals riders are not met by the intended controller are rise time, the start-up section of overshoot...

The waveforms of start-up are revealed as it can be seen the easy start of the converter is an innate conclusion of the addictiveness of DPWA controller. The dc offset change and slope of switching surface image on *x*1 − *x*2 plane are designed by the approaching process.

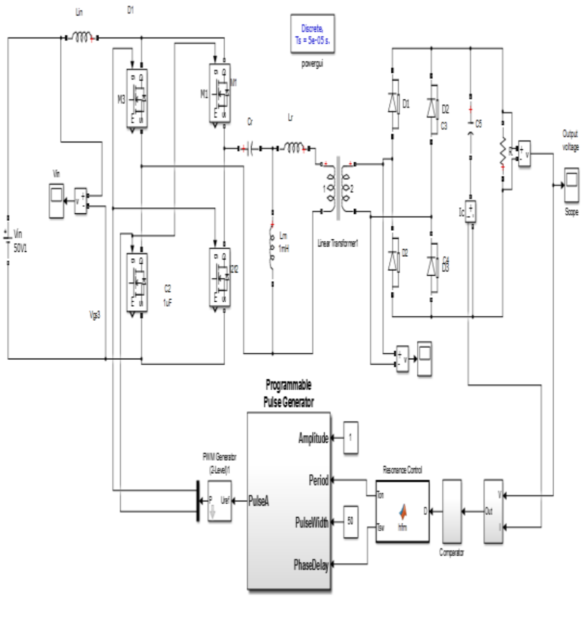


Fig 5.Simulation Diagram for dc-dc LLC type resonant converter

The project limits are the dc offset of relieving surface *m* and the PI controller amounts in the inner and the outer control loops, individually. The state course switches among the areas which are surrounded by the available limitations. The bandwidth of the inner loop is industrialized than loop signal differences and so higher than switching frequency 100 kHz.

The output of the outer loop is the output voltage and time-constant of output voltage 0.09 ms the dc input voltage functional to forthcoming The waveform is got with deference to voltage and time. In this input voltage is agreed as 40 (i.e.) V_{DC} **= 40 V.** The converter output voltage obtained from
planned LLC type resonant converter is revealed in the number given below.

It is got from the output of modifier which is rectified to a lively dc through the HF diode rectifier.

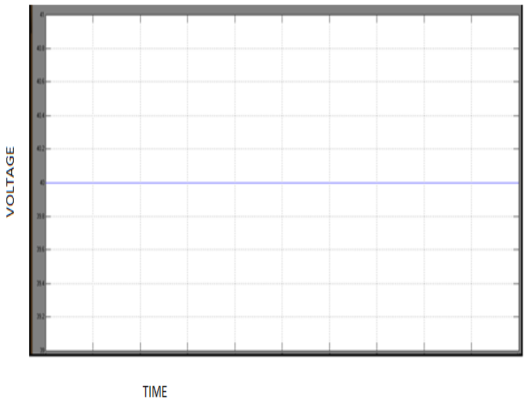


Fig 6 .Simulation result of input voltage

For the planned input Vdc = 30 V the output value gradually increases to 48 v and maintains a endless value of 48 V (i.e.) VO = 48 V. It demonstrations that the output voltage is 60% above the applied input voltage. The voltage gain for this converter is 160%. Here is no depression in voltage level.

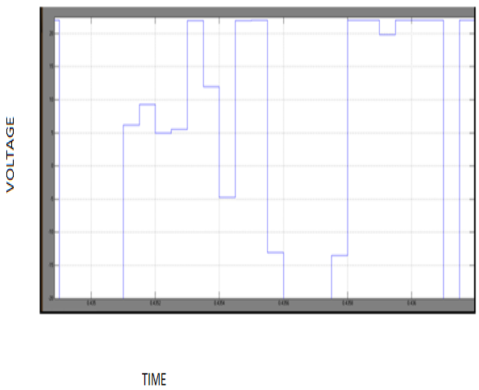


Fig 7 Simulation result of converter output voltage

The trouble refusal of the future control method is authenticated by the contribution voltage variation from48 to 75 V at t = 1 ms in Fig. 14. The output voltage is paid in few ms. The heftiness in front of indecision in the proposed method is validated by the load variation from 6 Ω to 4.5 Ω at t = 0.27 ms. The output voltage is compensated . Good voltage control and small transient response are gotten.

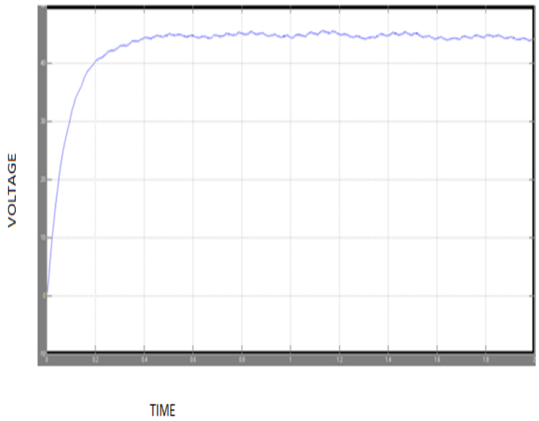


Fig 8 Simulation result of overall output voltage

VIII. CONCLUSION

For the constancy examination and control of resonant converters, a innovative hybrid control is obtainable. The projected hybrid DPWA control is based on non-averaged large size arrangement. The imitation result shows that the projected control method has apposite steady state and transient retort. It can be used for demonstrating, stability analysis, and manager enterprise for other power electronic converters. The planned converter shows development in the competence due to the augmented number of switches functioning with ZVS. Since the heat sinks are designated for the case of all-out input voltage at full load, a jagged delivery befalls at abridged load currents, but the switch currents also decrease with the load current. Further work is necessary in investigating the thermal distribution, finding the higher operating frequency limits and the trade-off between the negative effects of unbalanced current under reduced load and higher efficiency. Closed loop stability analysis of DPWA models can be solved by LMIs in the form of convex optimization problem

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