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MODELING AND SIMULATION OF LOW VOLTAGE POWER SUPPLY FOR ACTIVE PHASED ARRAY RADAR

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Abstract - This paper deals with the modeling and simulation of low voltage power supply (LVPS) unit to the ACTIVE PHASED ARRAY RADAR, which is used for sensing different targets at a time. This RADAR system contains flat bank of small identical antennas and huge number of transmitting and receiving modules for electronic scanning. This radar antenna requires power in different levels for various electronic devices. The proposed design of LV power supply will have the ability to manage temperature variations with high efficiency under different loading condition. The closed loop control such as voltage mode control and current mode control are used to regulate the output voltage with high switching frequency of 400khz has been designed. Simulations are performed using MATLAB / SIMULINK software.

Keywords *— Isolated converter topology, RADAR, solid state transmitters semi conductor devices, PI controller, Mat lab / simulink*

I. INTRODUCTION

RADAR is derived from the expression Radio detection and ranging. Radio waves were utilized to detect the target and to determine its distance or range. In simplest form, a radio transmitter emits electromagnetic radiation. When the radio wave is interrupted by any object such as plane, ship or mountain or other land mass, part of the energy is reflected back to a radio receiver located near the transmitter. The reflection is called an echo and the object reflecting it is called a target. The presence of an echo indicates that a target has been detected. Phased array radars can track or search for objects without moving its antenna [1]. A flat bank of small identical antennas each one capable of transmitting and receiving signals takes the place of the concave reflector and even as its beam scans expanses of sky the radar itself does not move instead the signal is deflected from target to target electronically steered through the principle of wave interference. This new technology is known as phased array.

In the present paper the phased array radar contains several subsystems where each subsystem requires the power in different level from the power generator. In the phased array radars there are huge number of (transmitting and receiving) modules. A group of such modules are packed as line replaceable units (LRUs).

The general block diagram of phased array radar system is as show in Fig. 1. A phased array antenna is composed of lot of radiating element each with phase shifter. Beams are formed by shifting the phase of the signal emitted from each radiating element, to provide constructive / destructive interference so as to steer the beams in the desired direction.

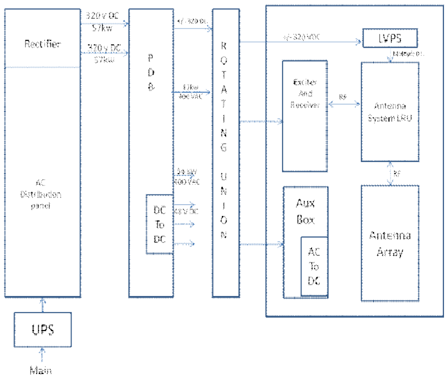


Figure 1. Block Diagram of phased array antenna power scheme

The main objective is to design different power supply modules having different voltage ratings as mentioned in the Fig. 2, with suitable circuit topology, so that the designed circuit has the ability to manage temperature variations, reliable with high efficiency

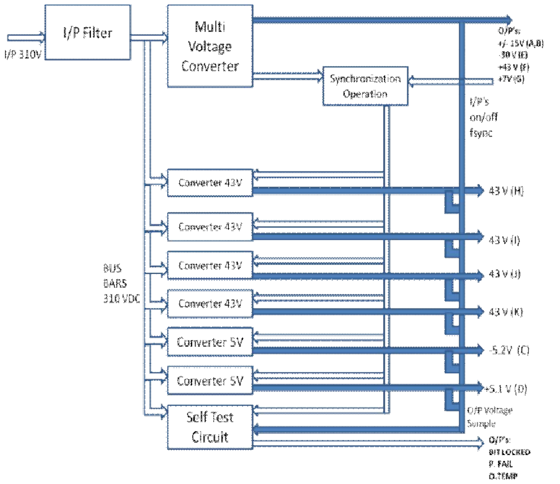


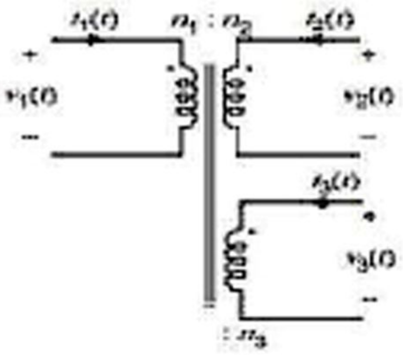
Figure 2. Antenna-LRU PSU block diagram

II. ISOLATED CONVERTER – A REVIEW

In the majority of applications, it is desired to incorporate a transformer into the switching converter, to obtain dc isolation between the converter input and output. For example, in off-line power supply applications, isolation is usually required by regulatory agencies. This isolation could be obtained by simply connecting a 50 Hz or 60 Hz transformer at the power supply ac input terminals [6]. However, since transformer size and weight vary inversely with frequency, incorporation of the transformer into the converter can make significant improvements: the transformer then operates at the converter switching frequency of tens or hundreds of kilohertz. The size of modern ferrite power transformers is minimized at operating frequencies ranging from several hundred kilohertz to roughly one Megahertz. These high frequencies lead to dramatic reductions in transformer size [2] [3]. When a large step-up or step-down conversion ratio is required, the use of a transformer can allow better converter optimization. By proper choice of the transformer turns ratio, the voltage or current stresses imposed on the transistors and diodes can be minimized, leading to improved efficiency and lower cost.

Multiple output power supplies have more than one DC output, often two or three. These are useful and cost-effective for systems that require multiple voltages. Multiple dc outputs can also be obtained in an inexpensive manner, by adding multiple secondary windings and converter secondary-side circuits. The secondary turns ratios are chosen to obtain the desired output voltages [9]. Usually, only one output voltage can be regulated, via control of the converter duty cycle, so wider tolerances must be allowed for the auxiliary output voltages. Cross regulation is a measure of the variation in an auxiliary output voltage, given that the main output voltage is regulated perfectly.

The basic operation of transformers in most power converters can be understood by replacing the transformer with the simplified model illustrated in Fig. 3.



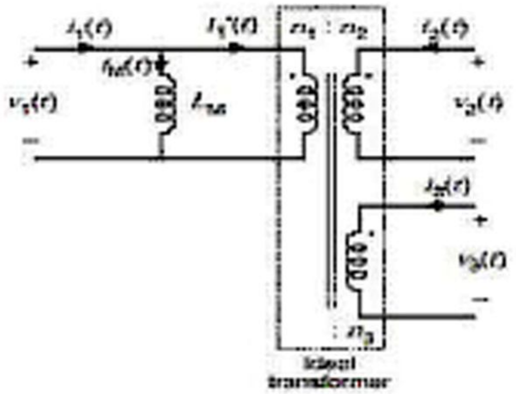


Figure 3. Isolation Transformer

The model neglects losses and imperfect coupling between windings; such phenomena are usually considered to be converter nonidealities. The model consists of an ideal transformer plus a shunt inductor known as the magnetizing inductance . This inductor models the magnetization of the physical transformer core, and hence it must obey all of the usual rules for inductors. In particular, volt-second balance must be maintained on the magnetizing inductance. Furthermore, since the voltages of all windings of the ideal transformer are proportional, volt-second balance must be maintained for each winding. Failure to achieve volt-second balance leads to transformer saturation and, usually, destruction of the converter. This means by which transformer volt-second balance is achieved is known as the transformer reset mechanism.

There are several ways of incorporating transformer isolation [4] into any dc-dc converter. The full bridge, half-bridge, forward, and push-pull converters are commonly used isolated versions of the buck converter. Similar isolated variants of the boost converter are known. The flyback converter is an isolated version of the buck-boost converter [7]. The full-bridge, forward, and flyback converters are briefly described in this section. The proposed isolated full bridge buck convertor is as shown in Fig. 4.

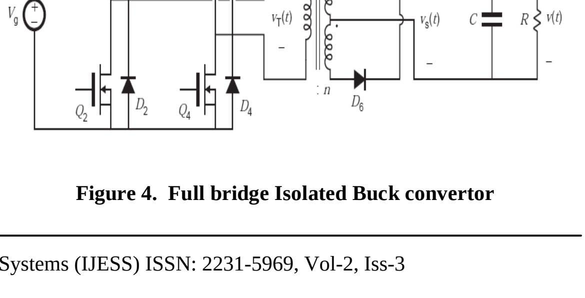


Figure 4. Full bridge Isolated Buck convertor

Power supply unit for multiple outputs with isolation transformer is as shown in Fig. 5

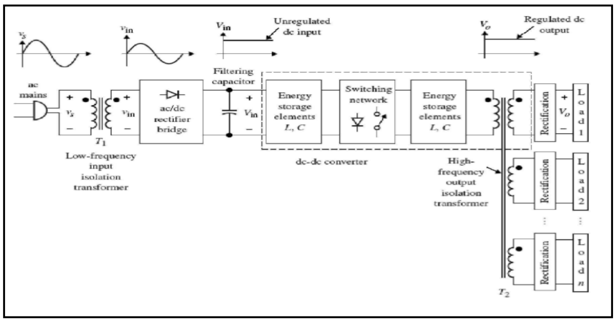


Figure 5. Power supply unit for multiple output

There are two popular methods of control for PWM switching power supplies they are voltage mode and current mode control. These centers around the parameters sensed within the switching supply; current or voltage can be sensed to provide consistent output voltages [11].

III.LVPS DESIGN

Transformer Design

The high frequency transformers are largely used in inverter and convertor applications. The switched mode power supplies (SMPS) require high frequency transformer if it has to maintain significant power level [4].

Following specifications are used in the design:

Output voltage - = 36.6v
Output ripple - % = 1% of
Output current – Io = 30A
Switching freq, f = 400kHz
Supply voltage – Vcc = 310V ±10%
Power rating = 1100 W
Core Material - Ferrite
Core set EELP 64
Combination: ELP 64/10/50 with ELP 64/10/50

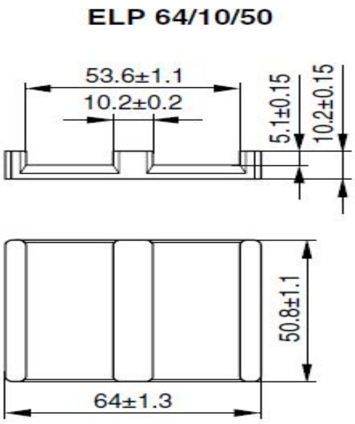
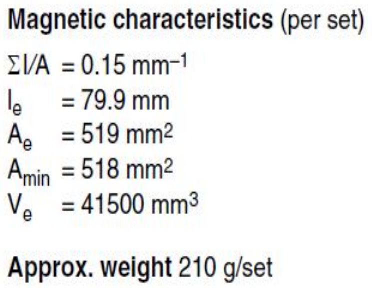


Figure 6. EE core transformer



Magnetic characteristics (per set)

$\Sigma l/A$ = 0.15 mm^{-1}
l_e = 79.9 mm
A_e = 519 mm^2
A_{min} = 518 mm^2
V_e = 41500 mm^3

Approx. weight 210 g/set

TABLE 1. Data sheet for ferrite material

Material	**AL value nH**	**μe**	**PVW/set**
N49	8000 ±30%	980	< 10.7 (50 mT, 500 kHz, 100 °C)
N87	12500 ±25%	1490	< 26.0 (200 mT, 100 kHz, 100 °C)

$$\text{Area of product } A_p = \frac{P_{o2} * 1 + 1/\eta}{4K_w J B_m f_s} \qquad (1)$$

$$\text{Primary turns } N_1 = \frac{V_{ccmax} D_{min}}{A_C B_m f_s} \qquad (2)$$

$$\text{Inductance L} = \frac{\mu_0 \mu_r A_C N_1 2}{l_m} \qquad (3)$$

$$\text{Resistance R} = \frac{\rho\, l_e N_1}{a_1} \qquad (4)$$

Assumptions

- Diode drop may be as high as 1.5 V for fast recovery diodes. It is safe to design for the worst case of = 1.5 V.
- Drop due to winding resistance of the inductor and transformer. It has been found that = 10% of is safe choice.
- At high frequencies, usually the core material choice is ferrite. It has a saturating flux density, of 0.3T, so the maximum allowable flux density in the core should be 0.2T or less.
- Another important design parameter is current density J. If J is chosen very low, then for a given current a very large conductor cross section is required (Their by demanding a large window area), which means that the resistance presented to the current flow will be low. A current density between 2-5 2 is found to be good compromise between conductor resistance and window area.

- Duty cycle in isolated convertors should not exceed 50% to avoid code saturation. So maximum duty cycle is 50% ±10%
- The window utilization factor K = 0.4 and the efficiency of transformer is taken to be high say 90%

Output Filter Design

The design approach will assume that the out ripple current must not exceed 30% of the load current (Peak to peak) [7]. To allow for a range of control, the pulse width at nominal input will be 30% of total period

$T_s = 1/f_s = 1/100k$

For a duty cycle of 45%, on period will be 4.5 micro sec.

It is normally assumed that the output capacitor size will be determined by the ripple current and ripple voltage specifications only.

$$\text{Output capacitor } C = 2\Delta I \times t_{on}/\Delta V_o{*}8$$

Where

- is current change in inductor during on period
- is ripple voltage (Peak to peak)
- is output capacitance value.

IV. SIMULATIONS

Fullbridge isolated converter:

The Simulation of the proposed convertor is carried out using Simpower system toolbox of MATLAB / SIMULINK software. Fig. 7 is a model for full bridge isolated buck convertor under open loop condition [5].

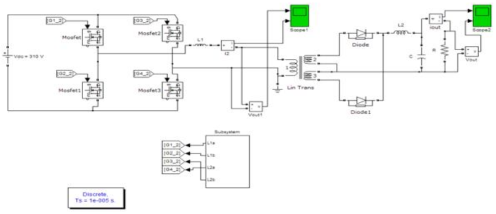


Figure 7. Open loop isolated buck converter.

Fig. 8 is a model of closed loop full bridge isolated buck convertor.

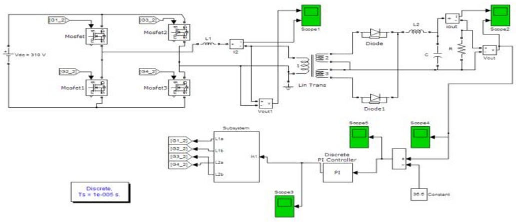


Figure 8. Closed loop isolated buck converter.

Multiple output converter:

Fig. 9 is a model of multiple output isolated buck convertor

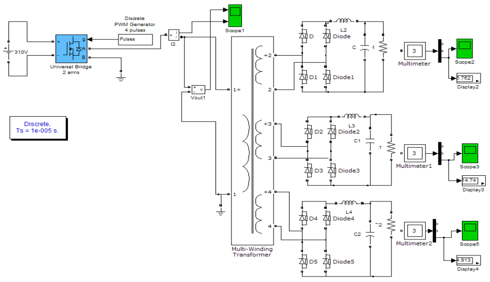


Figure 9. Multiple output isolated buck converter.

V. SIMULATION RESULTS

1. Fullbridge isolated buck converter:

Fig. 10 and 11 are the simulated results for open loop full bridge isolated buck convertor.

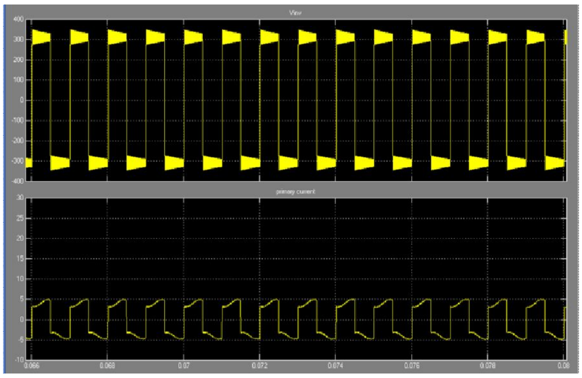


Figure 10. Inverter output voltage and current-open loop

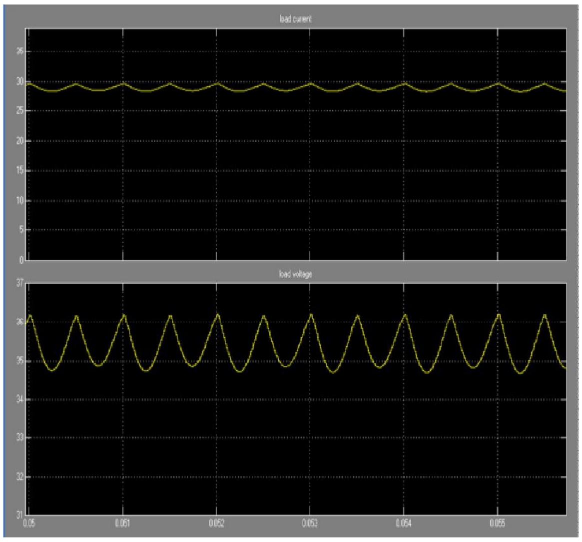


Figure 11. Dc output voltage and current-open loop

Fig. 12 is a simulated result for closed loop full bridge isolated buck convertor under load condition

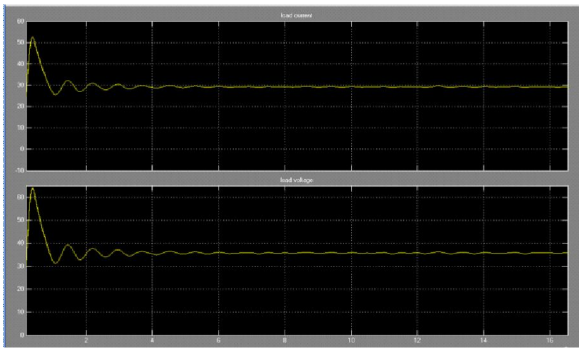


Figure 12. Dc output voltage and current-closed loop

Fig. 13 is the efficiency curve for the close loop system under normalized load

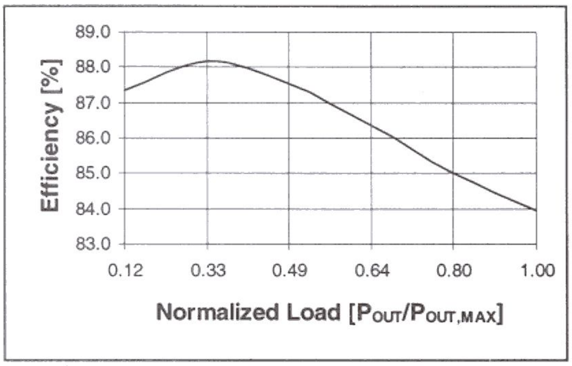


Figure 13. Efficiency curve-closed loop

As the graph shows, the efficiency peaks at about 88% then decreases due to the increasing resistive power losses. At full load, the efficiency is 84% which is close to the desired 85%. Once the circuit is built on a printed circuit board using the final planar magnetic components and optimized layout, it is very likely that the efficiency goal will be met.

2. *Fullbridge Isolated multiple output buck converter:*

Fig. 14 is a simulated result for multiple output load voltage for 7v/15A

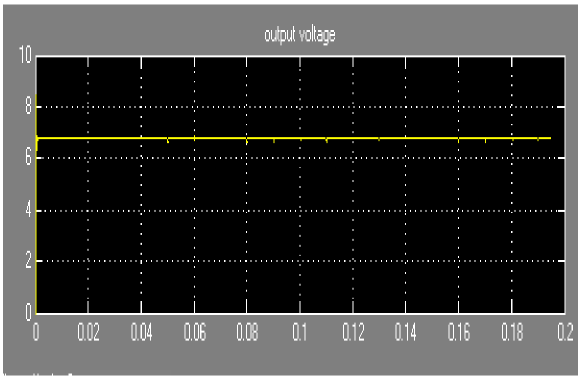


Figure 14. Multiple output load voltage-7v/15A

Fig. 15 is a simulated result for multiple output load voltage for 15v/7A

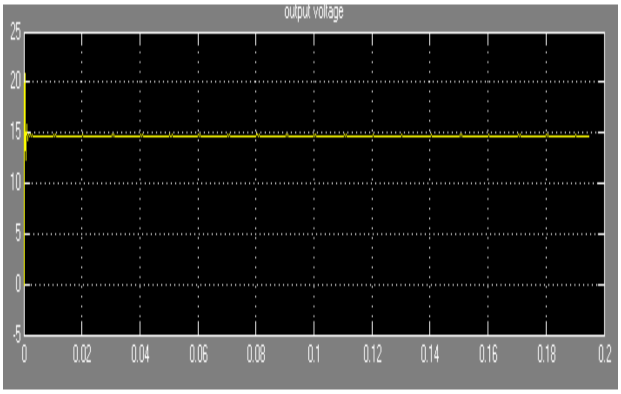


Figure 15. Multiple output load voltage-15v/7A

Fig. 16 is a simulated result for multiple output load voltage for 5.2v/8.5A

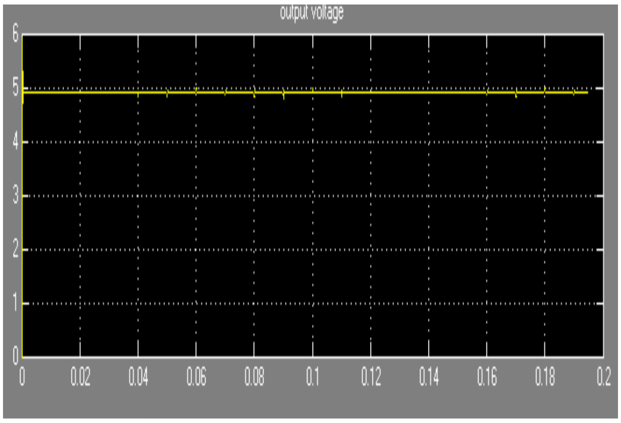


Figure 16. Multiple output load voltage-5.2v/8.5A

Fig. 17 represents the regulation curve for a multiple out put load voltage of 5.2v

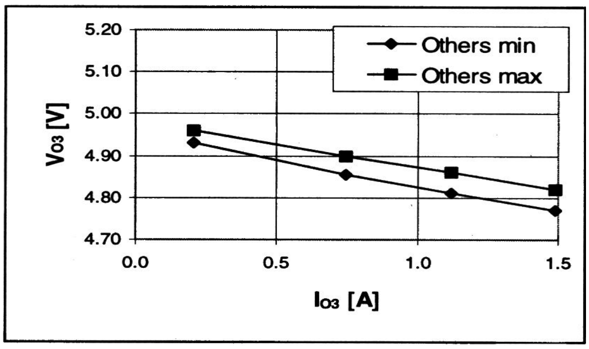


Figure 17. Line Regulation Vs. load current

The output regulation of Vo3 is very close to the predicted value[11]. From the above waveform we can observe that with the changes in the input voltage the output voltage is almost maintained constant [11]. So the line regulation is maintained approximately 0.1% of the load voltage .

VI. CONCLUSION

In the present work, by operating the converter at high frequency, the magnetic component in the converter can be made smaller which reduces the converter weight. The closed loop simulations is presented with PI controller to maintain constant load voltage with variations in the i/p voltage but controlling the switching action using PWM technique has a disadvantage of not reducing the switching losses to zero.

In ZVS quasi resonant converters, the power switches are operated with zero-voltage switching. Nonetheless, the rectifier diodes are switched with an abrupt change in voltage, which induces high-frequency ringings and power dissipation.

The performances of ZVS quasi resonant converters can be drastically improved by the introduction of the multi-resonant technique.

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