LITERATURE REVIEW

2.1. Buck-Boost Converter

A buck-boost DC-DC converter is an electronic circuit or electromechanical device that converts a direct current source from one voltage level to another. Power levels range from very low voltage (small batteries) to a very high voltage power transmission. Practical electronic transformers use switching techniques in converter mode DC-DC converts one DC voltage level to another, which may be higher or lower, by buffering the input power and then releasing that power to the output with a different voltage. Storage may be either in magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). This conversion method can either increase or decrease the voltage. Switching switch is often more energy-efficient (typical efficiency is 75% to 98%) than linear voltage regulation [14], which dissipates unwanted energy as heat. Rapid rise and fall of a semiconductor device are required for efficiency. However, these rapid transformations combine with parasitic planning effects to make circuit design challenges. The high efficiency of the transformer mode converter reduces the required heat dissipation.

However, these rapid transformations combine with parasitic planning effects to challenge circuit design. With high efficiency of the transformer mode converter reduces the dissipation of heat needed.

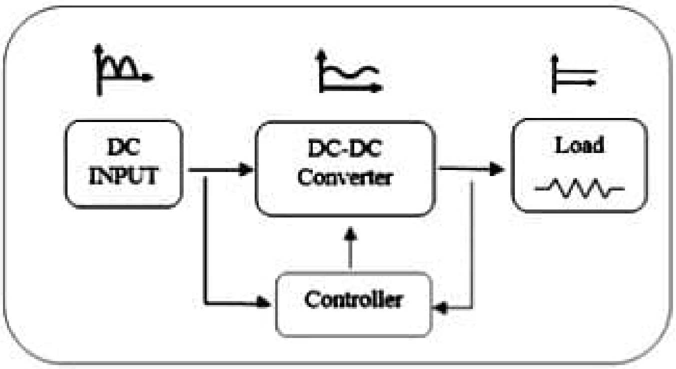

Figure 2. Block diagram Operation as a Boost- Buck Converter

principal work of the Boost-Buck Converter circuit. The DC-DC converter takes the ripple DC input and converts it to a better DC output for the load and the feedback from this operation drives back to set the converter to the right point of the duty cycle. The relationship between voltage and current was obtained by the impact factors and the equilibrium of the transformer such as the voltage ripple of the capacitor and the equilibrium state of the second voltage of the inductor's voltage.

2.1.1. Analysis of non-inverting buck-boost converter

Pulse-width modulation (PWM) signals are sent to the switches based on the input points from the controller [6]. The signals generated by the control circuit are used to operate the non-inverting circuit in buck-boost mode. Varied DC-DC conversion circuits with different operating properties are produced depending on the input to generate voltage and current for the target application [15].

In terms of the inductor current, constitutes inverters work in two modes: continuous conductive method (CCM) and discontinuous conductive method (DCM). It is in the CCM when the induction current is constantly more significant than zero. The transformer is in the DCM when the medium inductance current is poor due to high load impedance or poor shunt frequency.

Because of its great efficiency and effective utilization of semiconductor switches and passive components, CCM is chosen. Because the dynamic configuration of the transducer is limited in DCM, it necessitates remarkable control. To maintain the CCM, it is required to know the scoop's minimum value.

2.1.1.1. Continuous conductive method (CCM)

CCM is the state in the inductance current through the inductor L_1 above zero without any drop or distortion during the switching cycle [16]. When the SW1 is closed, and SW2 is open, the converter has two different functions as shown in Figure. 3 and 4; And from (t = 0 to t = TD) in this case, the converter is in the on state, since the V_s is the main voltage source and the rate of change of inductor current I_L is thus given by:

$$\frac{dI_L}{dt} = \frac{V_s}{L_1} \tag{1}$$

Figure 3. Boost-Buck on state first condition

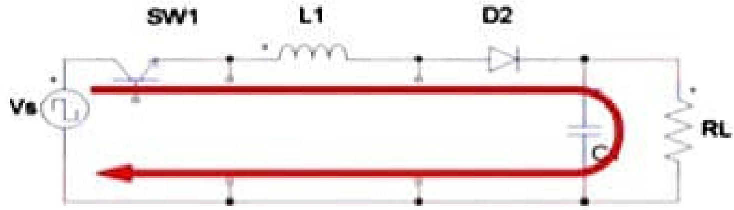

Figure 4. Boost-Buck on state second condition

The duty cycle D represents the fraction of time T when the switch is on or off (0, 1), and it represents the range working for both unctions in the on-state. Therefore, SW1 is still closed in this case, and the circuit is still in the on-state. At last, the on-state increment of I_L is given by:

$$\Delta I_{L_{On}} = \int_0^{DT} dI_L = \int_0^{DT} \frac{V_s}{L_1} dt = \frac{V_s DT}{L_1} \qquad (2)$$

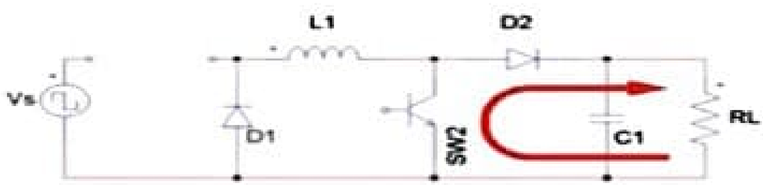

Figure 5. Boost-Buck off state first condition

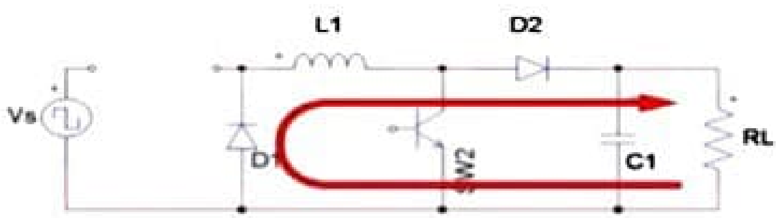

Figure 6. Boost-Buck off state second condition

and SW2 is closed, as shown in Figure 5, while the current movement continues through the SW2 through the diode D2, which allows this current to flow as a result of the zero voltage drop on the capacitor. In accordance with figure 6. The current passes through the diode D1 sequentially through the inductor L1, which helps to be sufficient to maintain stability Voltage. This process allows the proportionality between the zero voltage in this case and the current I_L passing through the circuit and provide the load with stable output voltageV_o.

$$\frac{dI_L}{dt} = \frac{V_o}{L_1} \tag{3}$$

Therefore, the variance I_L during the pause period.

$$\Delta I_{L_{OFF}} = \int_0^{(1-D)T} dI_L = \int_0^{(1-D)T} \frac{V_o}{L_1} dt = \frac{V_o(1-D)T}{L_1} \tag{4}$$

Because we assume the converter functions under constant conditions, the amount of energy stocked in each component at the onset and offset of the replacement cycle must be the same. As a result, the inductor's power is provided by:

$$P = \frac{1}{2} L_1 I_L^2 \tag{5}$$

According to Kirchhoff Current Law, the value of I_L at the start of the on-state should be similar to the value I_L at the end of the off-state. However, during the on and off stages, the total variety of I_L forms should be zero.

$$\Delta I_{L_{On}} + \Delta I_{L_{OFF}} = 0 \tag{6}$$

Replacing these values by its expression results gives the following

$$\Delta I_{L_{On}} + \Delta I_{L_{OFF}} = \frac{V_s DT}{L_1} + \frac{V_o(1-D)T}{L_1} = 0 \tag{7}$$

By subtracting all the values

$$\frac{V_o}{V_s} = -\frac{D}{1-D} \tag{8}$$

This, in turn, results in

$$V_o = -V_s \frac{D}{1-D} \tag{9}$$

Due to the circuit duty cycle and the duty cycle transition from on-state to off-state, the contradiction of the output voltage is always negative, and its modulus increases with D, theoretically reaching negative infinity when D accession on-state. Depending on the polarity, this converter is either a boost converter (step-up) or a buck converter (step-down converter). As a result, it is known as a buck-boost converter.

2.1.1.2. Discontinuous conductive method DCM

The non-continuous conduction method is rectifier activated when the sum of control required for the load is little, and the current across the inductor drops to zero amid the portion of the obligation cycle. In this case, the control can be exchanged in less than the complete substitution period, whereas both (SW 1, SW2) are opened, as appeared in Figure 7.

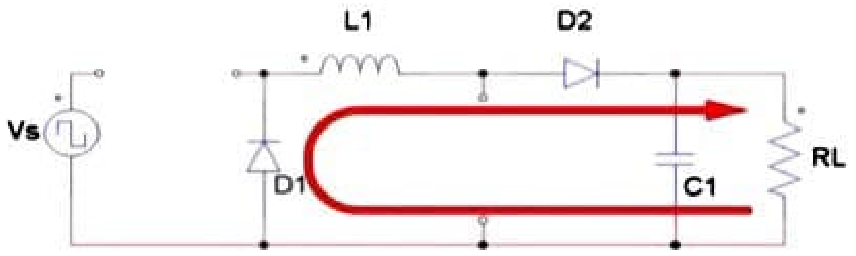

Figure 7. Boost-buck DCM

The inductor is discharged in this period. And this will be represented by changing both switches. Even if the variation is minor, it has a significant impact on the output voltage. Furthermore, because the inductor current is zero at the start of the period, the boundary value $I_{L_{max}}$ Equations may be computed.

$$I_{L_{max}} = \frac{V_s DT}{L_1} \tag{10}$$

During the off phase, I_L drops to zero after $\delta.T$:

$$I_{L_{max}} + \frac{V_o \delta T}{L_1} = 0 \quad (11)$$

From the previous, δ can be represented as.

$$\delta = \frac{V_s D}{V_o} \quad (12)$$

The output current I_o is equal to the total diode current I_D. The diode current is similar to the inductor current during the off condition. Therefore, the output stream might be written as follows:

$$I_0 = I_D = \frac{I_{L_{max}}}{2}\delta \quad (13)$$

$I_{L_{max}}$ and δ, according to each result from the expressions, can be replaced by:

$$I_o = I_D = \frac{V_s D T}{2L_1}\frac{V_s D}{V_o} = \frac{V_s^2 D^2 T}{2L_1 V_o} \quad (14)$$

As a result, the voltage gain at the output can be represented as

$$\frac{V_o}{V_s} = \frac{V_s D^2 T}{2L_1 I_o} \quad (15)$$

On the other hand, comparing the continuous method, CCM seems more complicated in the output voltage than the DCM. The latter depends on more than one factor in the operating cycle in addition to the effect of the output voltage on the process as it depends on the value of the inductor, the input voltage, and the output current.

2.1.1.3. The boundary between continuous and Discontinuous methods (buck-boost converter)

To be more precise, the DCM works when there is a low current at the load, and the CCM works in both cases and gives results more capable than the DCM, and it can be considered to reach between both the DCM, CCM, and this can be achieved through

$$D + \delta = 1 \tag{16}$$

$I_{o_{lim}}$ is output current, at the limit between CCM and $I_{o_{lim}}$ DCM, and it can be represented as

$$I_o = I_D = \frac{I_{L_{max}}}{2}(1 - D) \tag{17}$$

By the expression of $I_{L_{max}}$ given in section 2.1.1.2.

$$I_{o_{lim}} = \frac{V_s DT}{2L_1}(1 - D) \tag{18}$$

Since the current is based on the distinction between CCM and DCM, the equation can be formulated by $I_{o_{lim}}$.

$$I_{o_{lim}} = \frac{V_s DT}{2L_1}\frac{V_s}{V_o}(-D) \tag{19}$$

2.2.Magnetic resonance coupling

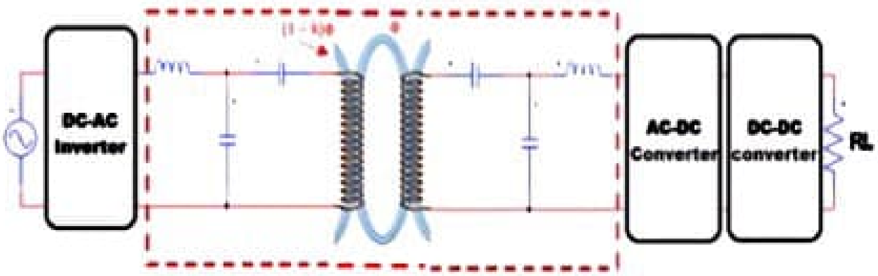

Figure 8. The flux between primary and secondary coil

The main system of the WPT is the transmitting circuit. To make the system work at high efficiency [13], [17], [18], the transmitter circuit must be excellent and have high accuracy. However, magnetic resonance is the function to make transmitting signal direct the circuit to a better standard.

2.2.1. Analysis of resonance coupling

Figure 9. Resonance Coupling

Figure. 8 and 9. Demonstrate a double side LCCL resonance coupling combination that clarifies the flux between the essential and the auxiliary coil [11], [12], [19], [20]. While the essential coil stores the power from the source and provides the magnetic fluxΦ, the auxiliary coil helps generate the voltage on it, allowing the power to be transferred more easily to the receiver section. Shockingly, a few sections of these flux rounds are not gotten to the last coil portion that will influence the coupling coefficient k.

The total magnetic flux will be

$$\Phi_T = k\Phi \tag{20}$$

The primary to secondary coil turn ratio number n can be defined as

$$n = \frac{n_1}{n_2} \tag{21}$$

Flux ϕ_T can be calculated while losses in the coupling coefficient are taken into consideration.

$$\Phi_T = (1 - k)\Phi_T \tag{22}$$

The coupling coefficient K is a coefficient proportional to the distance d between primary and secondary coils.

$$k \; \alpha \; \frac{1}{d} \tag{23}$$

Moreover, mutual inductance M between the couplings will be

$$M = k\sqrt{L_p L_s} \tag{24}$$

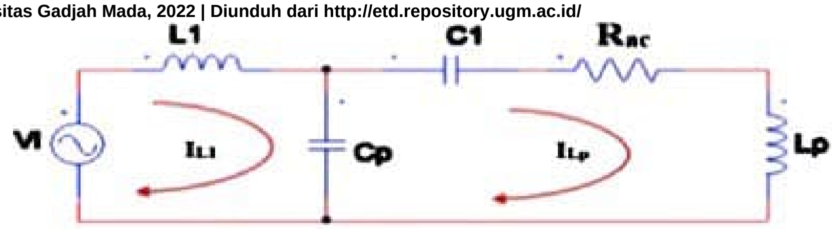

Figure 10. Primary LCCL side

Figure 10. describes the simplified model for the primary side of the resonance coupling L_p , the primary inductor and L_s as the secondary inductor. While R_{ac} the load of the power consumption of the secondary side, and according to the voltage and current Kirchhoff's low. We can define

$$I_{L1}\left(j\omega L_1 + \frac{1}{j\omega C_p}\right) - I_{Lp}\left(\frac{1}{j\omega C_p}\right) = V_i \quad (25)$$

$$\left(\frac{1}{j\omega C_1} I_{L1} + j\omega L_p + R_{ac}\right) I_{Lp} = \left(I_{L1} - I_{Lp}\right)\frac{1}{j\omega C_1} \quad (26)$$

In connection with the frequency signals and considering the impedance of the primary side.

$$\omega = \omega_o = \frac{1}{\sqrt{L_p C_p}} \quad (27)$$

Eliminating equation 25 from 26.

$$I_{L1} = V_i \omega_o^2 C_p^2 \left(R_{ac} + j\omega_o L_p - \frac{1}{j\omega_o C_p} - \frac{1}{j\omega_o C_1}\right) \quad (28)$$

Since all of this consideration in the ideal calculation, the circuit works with a pure resonance. Then it can be obtained as

$$j\omega_o L_p - \frac{1}{j\omega_o C_p} - \frac{1}{j\omega_o C_1} = 0 \quad (29)$$

From equation 29. the capacitance of this resonance can be calculated by

$$\frac{L_P}{L_1} - 1 \tag{30}$$

The same operation can be obtained for the calculation of the secondary side to give.

$$C_2 = \frac{C_s}{\frac{L_s}{L_2} - 1} \tag{31}$$

While in the case of ω_o in the secondary side.

$$\omega_o = \frac{1}{\sqrt{L_s C_s}} \tag{32}$$

2.2.1.2. Full equivalent LCCL circuit

To simplify the circuit analysis and study the equivalent circuit, all aspects must be considered. The circuit must be fully linked so that the inputs and outputs are integrated. The calculations can be simplified to make the calculation and to follow newton's law of power and electromagnetic induction. Therefore, the circuit was connected and analyzed based on the perspective of the primary side, as appears in Figure 11.

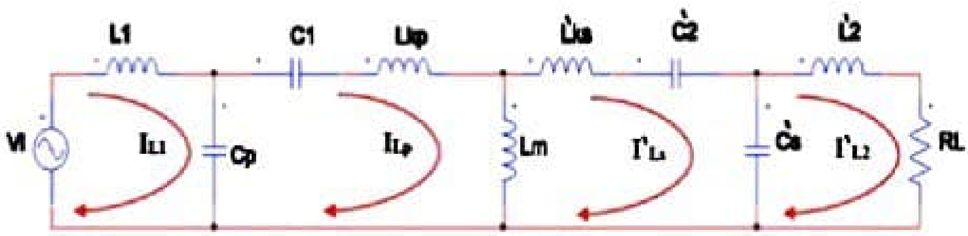

Figure 11. LCCL Circuit Equivalent

The power is proportional with the resistance of the primary as well as the losses $P_1 \, \alpha \, R_P \, \alpha \, losess$. As a result, any increases in the primary's powers or resistance will exacerbate the losses.

coefficient among the primary and secondary coils, with the consideration of the turn ratio number n. the secondary side parameter becomes.

$$\begin{gathered} L'_{ks} = (1-k)L_s n^2 \\ L'_2 = L_2 n^2 \\ C'_s = \frac{C_s}{n^2} \\ C'_2 = \frac{C_2}{n^2} \\ I'_{L2} = \frac{I_{L2}}{n} \\ L_{kp} = (1-k)L_P \end{gathered} \tag{33}$$

For higher efficiency, the coupling coefficient k of the primary should be much smaller than the load R_{ac}. So, the primary resistance can be calculated as

$$R_{ac} \approx \frac{\mu_P}{\mu_P}\,\mathrm{k} \tag{34}$$

The efficiency ratio can be found by the relation between the primary and secondary side

$$\mu_r = \frac{\dfrac{\omega_0^2 L_P}{R_{ac}}}{\dfrac{\omega_0^2 L_s}{R_L R_{ac}}} \tag{35}$$

Finally, the quality factor Q_f in this case, will be

$$Q_f = \frac{\dfrac{\omega L_P}{(\omega_0 M)^2}}{R_{ac}} \tag{36}$$