ANALYSIS AND IMPLEMENTATION OF 3 LEVEL DC TO DC CONVERTERS

Kishore MP,
Assistant Professor,
Department of Electrical Engineering,
JSSATEN, UP
Rangma Tiwari,
Engineering student.

Abstract--- The research presents a model of a Microcontroller based differential relay for protection of a transformer with multiple auto close settings. The differential Protection scheme which utilizes the current difference between terminals of the transformer to detect faults is employed utilizing Arduino and Current sensors. Arduino is used to detect the abnormal condition and send the trip signal to electromechanical relay. The circuit is designed in Proteus and results were analyzed in MATLAB. Primary Current of transformer v/s Time plot was found satisfactory. The additions of auto close setting in the relay increase its application to standby transformers and Bus Couplers. A hardware prototype of the same was created. Simulation of a three-phase transformer was also performed on Proteus software.

***Key Words*—Arduino, Buck Converter, Boost Converter, Continuous Conduction Mode (CCM), Discontinuous Conduction Mode (DCM)**

I.INTRODUCTION

DC-DC converters are widely used to efficiently produce a regulated voltage from a source that may or may not be well controlled to a load that may or may not be constant. This paper briefly introduces DC-DC converters, notes common examples, and discusses important datasheet parameters and applications of DC-DC converters. DC-DC converters are high-frequency power conversion circuits that use high-frequency switching and inductors, transformers, and capacitors to smooth out switching noise into regulated DC voltages. Closed feedback loops maintain constant voltage output even when changing input voltages and output currents. At 90% efficiency, they are generally much more efficient and smaller than linear regulators. Their disadvantages are noise and complexity. DC-DC converters come in non-isolated and isolated varieties. Isolation is determined by whether or not the input ground is connected to the output ground. Four common topologies that makers might find useful are the buck, boost, buck-boost, and SEPIC converters.

II.TYPICAL BUCK CONVERTER

A Buck Converter is a voltage step down and current step-up converter; it is a DC-DC converter. Buck converter is the most basic SMPS topology. It is widely used throughout the industry to convert a higher input voltage into a lower output voltage. The buck converter (voltage step-down converter) is a non-isolated converter. The Buck Converter is used in SMPS circuits where the DC output voltage needs to be lower than the DC input voltage.
The DC input can be derived from rectified AC or from any DC supply. It is useful where electrical isolation is not needed between the switching circuit and the output, but where the input is from a rectified AC source, isolation between the AC source and the rectifier could be provided by a main isolating transformer.

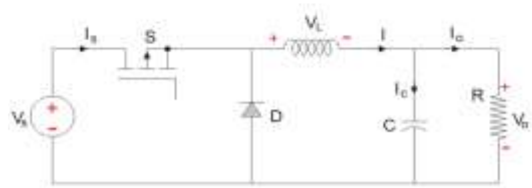

Fig 1. Circuit for typical buck converter

III. OPERATIONS OF BUCK CONVERTER

The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode). In the idealized converter, all the components are considered to be perfect. Specifically, the switch and the diode have zero voltage drop when on and zero current flow when off and the inductor has zero series resistance. Further, it is assumed that the input and output voltages do not change over the course of a cycle (this would imply the output capacitance as being infinite).

The dc-dc converters can have two distinct modes of operation: Continuous conduction mode (CCM) and discontinuous conduction mode (DCM). In practice, a converter may operate in both modes, which have significantly different characteristics. Therefore, a converter and its control should be designed based on both modes of operation. However, for this course we only consider the dc-dc converters operated in CCM (Buck Converter).The dc-dc converters can have two distinct modes of operation: Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM). In practice, a converter may operate in both modes, which have significantly different characteristics. Therefore, a converter and its control should be designed based on both modes of operation. However, for this course we only consider the dc-dc converters operated in CCM (Buck Converter).

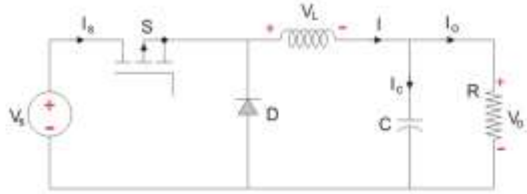

Fig 3.1: Typical Buck Converter

Table 3.1 Switching Control With Pin Number

Switch pair	**Pin Number**	**Time for which HIGH**
S1,S3	3,6	500ms
S1,S2	3,5	500ms
S2,S4	5,9	500ms
S1,S2	3, 5	500ms

Fig 1. Typical Buck Converter

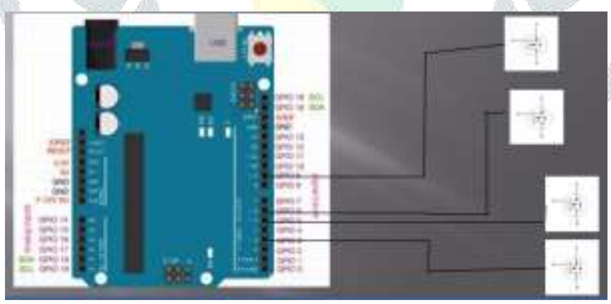

Fig 3.2: Schematic Diagram Of Microcontroller

V. PROGRAM FOR SWITCHING CONTROL

```
Void setup()
{
pinMode(3,OUTPUT);
pinMode(5,OUTPUT);
pinMode(6,OUTPUT);
pinMode(9,OUTPUT);
}
Void loop()
{ digitalWrite(3,HIGH);
```

```
digitalWrite(6,HIGH);
deay(500);
digitalWrite(5,HIGH);
digitalWrite(6,LOW);
delay(500);
digitalWrite(3,LOW);
digitalWrite(9,HIGH);
delay(500);
digitalWrite(3,HIGH);
digitalWrite(9,LOW);
delay(500);
```

IV. WORKING OF 3 LEVEL BUCK CONVERTER

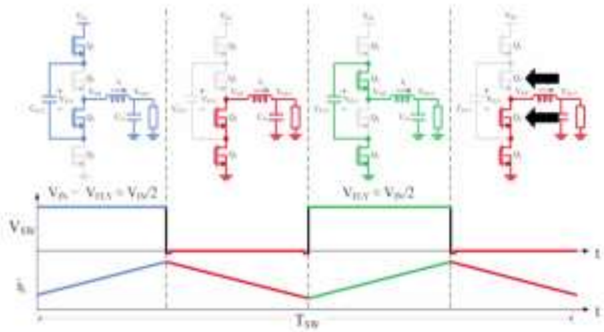

Fig 4.1 Working Of 3 Level Buck Converters

Imagine a 12 volt input used to charge a 4 volt battery. In this case the converter will operate by alternating the switch node between Vin/2 and ground as shown in above figure. The cycle consists of 4 stages. We start the cycle by switching ON Q1 and Q3 presenting Vin – V(FLY) = Vin/2 at switch node and at the same time the capacitor C(FLY) gets charged while the inductor gets energize because the output is lower than the switch node voltage.

During the second stage Q1 is turned OFF and Q4 is turned ON bringing the switch node to ground. This leaves the capacitor C(FLY) disconnected an de energizes the inductor.

In the third stage the controller turns of Q3 and turn ON Q2 connecting the C(FLY) capacitor directly across the switch node. This results in discharging the capacitor voltage and energizing the inductor. It is important to note that whatever charge was added to C(FLY) during first stage should be removed from C(FLY) during the third stage in order to maintain the capacitor balanced at Vin/2 at steady state operation.

Finally in fourth stage Q2 is turned OFF and Q3 turns back ON connecting the switch nod directly to ground, this leaves the capacitor disconnected and de-energizes the inductor once again in preparation for the next cycle.

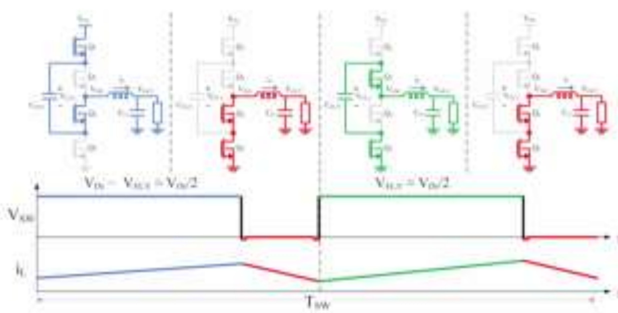

Fig 4.2: Three- Level Buck Converter

As the input voltage decreases the controller increases the duration of first and third stage in other words increases the duty cycle in order to maintain a regulated output voltage. This is the effect of reducing the inductor current ripple until a minimum is reached when the input is exactly equal to twice the output voltage.

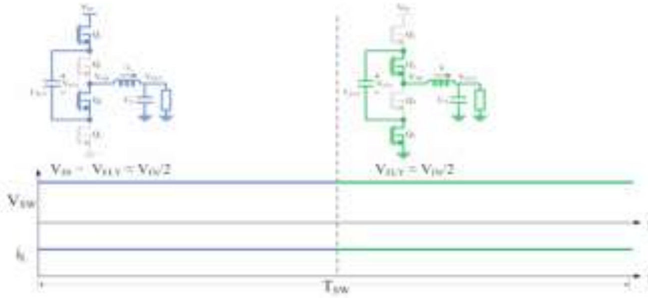

Fig4.3 Working Of 3 Level Buck Converters

At this point the switch node remaining at Vin/2 at all the time while the controller changes between stage 1 and stage 3 in order to charge and discharge the capacitor C(FLY) each cycle.

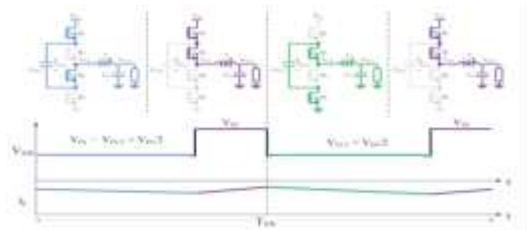

Fig4.4 Working Of 3 Level Buck Converters

As the input voltage continues to decrease, the controller continues to increase the duty cycle until Q1 and Q3 are turned ON during the same time period. In this case the switch nodes are alternating between Vin and Vin/2. Again there are alternating stages where C(FLY) charge an discharge.

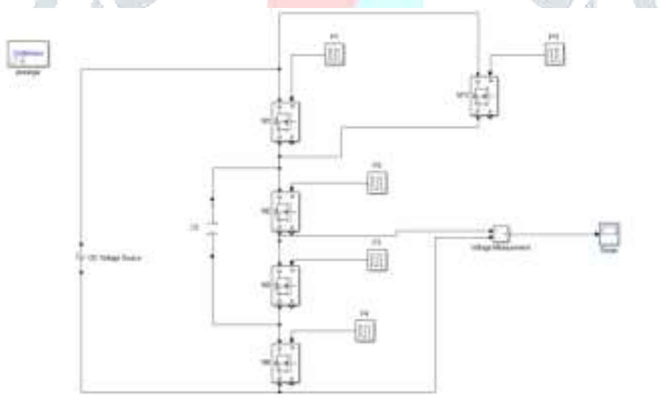

Fig 4.5: Simulink Model

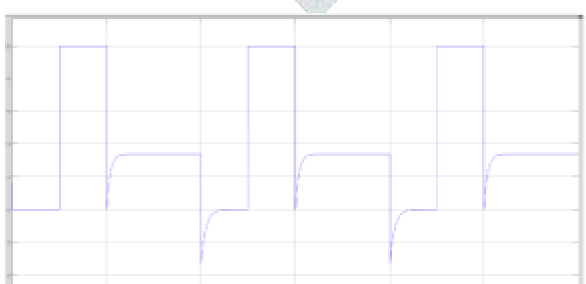

Fig 4.5: Output Of Simulink Model

V. FUTURE WORK

This work demonstrates a solution for high-power, high-voltage DC/DC conversion using multi-phase three-level DC/DC converter with interleaving method and integrated coupled inductors. To further extend the depth for this research area, the following topics can be continued

1). Study the design of integrated coupled inductors with different magnetic materials to optimize its power density, performance and efficiency.

2). Expand the concept of integrated magnetic to three-phase three-level interleaved DC/DC converter. A systematical magnetic design method using equivalent inductance analysis can be developed for three-phase interleaving, or even for four-phase interleaving DC/DC conversion.

3). Study the control strategy for the three-level power conversion system, including both the DC/AC inversion stage and the DC/DC conversion stage, and the possible issues for the interaction of the two stages in control

CONCLUSION

In this study, a new multi-input dc/dc converter having same number of active switches as of three-level isolated dc/dc converter without introducing additional switching actions is proposed. The circuit analysis and design consideration has been provided in detail. With proper selection of input inductors, autonomous load sharing can be achieved. To verify the operation of the converter, simulations of different parameters have been performed. A low voltage laboratory built prototype has been designed and tested under varying input voltages and duty cycles. The results prove the effective integrated operation of input sources with three-level isolated dc/dc structure, through operating four switches in a phase-shifted manner without introducing control complexity.

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ABOUT THE AUTHOR

Kishore MP,
Assistant Professor,

Mr. Kishore M P received Bachelor of Engineering degree in Electrical and Electronic Engineering from Vidya Vikas Institute of Engineering and Technology (VVIET), Mysuru, India, in 2014 and M.Tech degree in Power Systems from Don Bosco Institute of Technology (DBIT), Bangalore, India in 2016. Currently working as Assistant Professor in Electrical Engineering Department at JSS Academy of Technical Education, NOIDA. His research interests include Renewable Energy Resources and Power factor improvement techniques.

EMAIL : kishoremp@jssaten.ac.in

Rangma Tiwari
Engineering student

Ms. Rangma Tiwari is currently a second-year student, pursuing BTech degree in Electrical engineering from JSS Academy Of Technical Education, Noida,India . Her core interest lies in Speech signal processing and sensors, she is presently working on a Voice recognition, hand gestured Arduino device for the same.