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DESIGN OF A HIGH SIDE CURRENT SENSE CABLE DROP COMPENSATION CIRCUIT FOR LONG DISTANCE DC TRANSMISSION

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ABSTRACT

Long distance power transfer is one of the major problems of renewable energy source located in far-off and secluded areas from the major load center. This is due to the increase in power loss along the transmission caused by the length of the transmission medium used for the power transfer of such distances. LTSpice was used to simulate the circuit and the results were plotted using MATLAB in order to conjure the result of the trials with respect to distance. Having 10 trials, the distance increments by 25 where the resulting voltage is directly proportional to the increase in each trial. The present study aims to study and develop an external cable compensator in minimizing the voltage loss for the supply of power source for CCTV cameras.

Keywords: attenuation, cable compensator, converter, feedback, and load balancing.

INTRODUCTION

Security is one of the things needed for a living human being to survive. Life is filled with dangers and perils, both in your own home and outside. Thus it is vital for humans to create and invent mechanism and technology to maximize their security, such as collecting food supplies, developing environmental conditions to further growth and well-being and, build shelter. Whenever people go outside, as they walk along the streets albeit they are just near their own house, they would always be cautious and protective with themselves and their belongings. Even if they were inside an establishment, they would not be complacent and put their guard down which started to become a practice for people especially when they are outside their own home. This was noticed by shop owners and has taken action to ensure that their customers would fill secure inside.

CCTV or also known as closed circuit television is a video surveillance, wherein it permits the use of video cameras to display the interior and exterior of a place, transmitting the signal to a limited amount of monitors. As a way to feel secure and safe, they install CCTVs in every corner possible to prevent crimes or to catch the perpetrator. According to an evaluation by the PNP of reports from January to June 2014, 87% of crimes in Metro Manila were solved when committed in places with a CCTV, compared to only 62.5% in places without them. The study also saw a success rate of 58.18% when it came to crime prevention in places with a CCTV, versus 41.8% in places without them. [1]

The CCTV cameras have minimum required power and if it is not met, it could cause interference in the video feed that could cause the image to be coarse that is undesirable. One of the major causes of this is the attenuation of power in the cable that is used to connect the CCTV to the supply. Having an equation:

$$P_{loss} = I^2R \tag{1}$$

Initially, the electrical conductor used for transmission of power acts as impedance. This impedance greatly increases as a result of longer distance of transmission. In this manner, there is an accumulated voltage drop across this transmission medium causing the decrease of voltage transmitted to the load.

RELATED LITERATURE

According to Greg Reed, with the development of technologies nowadays, it motives the growth of the DC loads equivalent of some basic AC home appliances such as LED lights and fans. After 20 years, an increase of almost half of the DC loads used nowadays was to be expected [2]. These would cause the majority of the devices used at home to be at a low DC voltage around 5V to 24V. Similar to the growth of the DC loads are the residents use of renewable energy sources such as Solar PV energy, Hydroelectric energy, and Geothermal energy. This causes a much environment-friendly energy harvesting and much cheaper electrical cost. The main reason for losses in transmission and distribution lines is the resistance of conductors against the flow of current. If the conductor's temperature increases the resistance, there will be a rise of losses [3]. Power losses can be considerably lessened by frequently adjusting the cable operating voltage according to the instantaneous wind farm power production [4].

However, one major problem of these renewable energy sources is the long-distance power transfer, especially, for sources located far away from the major load centers [5]. This is due to that the level of power transfer, the power loss, and the transmission distance is directly proportional respectively with one another. The transmission distance has a great impact in the total loss of the power system. Attenuation is a term that refers to any reduction in the strength of the signal. The attenuation rate of direct current in power cable is it depends on the resistivity of the wire. As the diameter increases, the resistance decreases. According to the US Energy data of 2014, the lost energy is about 8% of the net generated energy. This power loss is dissipated through heat in the conductor wires causing attenuation of the transmitted energy. The attenuation rate of direct current in a power cable is it depends on the resistivity of the wire. This is related to the diameter, material and temperature of the wire. [6]. It also refers to a loss introduced by a circuit or a component. If the output signal is lower in amplitude than the input, the circuit has loss or attenuation. The establishment of distribution in this generation has a very large impact on power loss and voltage distribution because the flow of the load has changed [7]. Power loss is also called attenuation and it results in a reduction in the power of the wave of light as it travels down the cable. Semiconductor device data sheets can also use to estimate the power loss of a device in a dual active bridge, it is also a model to develop the semiconductor devices for power losses [8].

The conductor wire used as a transmission medium in the transmission and distribution of electrical energy from the power source to the load consist of various power losses. Some of these power losses are technical losses which are losses in drivers, losses by corona effect, losses in the iron of transformers, losses by eddy connectors, losses in connectors, dielectric losses [9].

In the research of Vinicius Cardoso de Paula it focused on a problem related to PWM motor drive systems with long cables, they made a system in which the rectifier and inverter are not together in a long dc cable. When the copper and energy is connected one of them will increased and due to distinctiveness of AC and DC cables, there will be a possibility that one of them also will decreased, this results into an overall economy figures are always favor in DC transmission drive system [10]. There are methods in how to regulate voltage deviations and in reducing power loss of a transmission system, this method is called Rule-based method. The objective of this rule is to find the most effective control device that can minimized the violation of the voltage of the system. In short, the most effective control device is by using the minimum electric distance of the system [11].

The problem of variable supplies of electrical energy in a distribution network is the voltage fluctuations that it turns into a short-circuit ratio and it affect some network because of the active losses of a system. To know the methods that these researchers used in calculating the electric distance, they measure the active resistance and inductive reactance by simplifying the series-parallel network and calculating the active and inductive resistance in the value of active and passive losses [12].

The converter must be able to adjust compensation depending on the power factor, but still the effect of unsymmetrical cables cannot be compensated. The voltage calculation with unbalance load totally lacks to include the additional voltage drop that is added due to returned current in the neutral conductor using unbalanced load conditions [13].

Cable compensation is used to compensate the cable voltage drop by linearly increasing the output voltage with the output current. The concept of cable compensation is quite similar to adaptive voltage positioning scheme for powering central processing unit core voltage applications where the output voltage is designed to be directly or inversely proportional to the output current for achieving the specific requirement [14].

In line with the following concerns, a device have been designed to provide appropriate supply to the load along far distances using automatic cable compensation and load balancing circuit. It would determine the sufficient amount of supply to be transmitted to the transmission line for both the transmission medium and the load. It would automatically provide power across the transmission line sufficient enough to accommodate both the transmission medium and the load. It uses a negative feedback circuit in determining the appropriate supply to compensate for the transmission medium.

METHODOLOGY

LTSpice is freeware computer software implementing a SPICE electronic circuit simulator, produced by semiconductor manufacturer Linear Technology, now part of Analog Devices [15]. It assumes a vital role for the user to simulate the circuit as realistic as possible and helps in understanding the theoretical aspects of circuit design very easily.

MATLAB, a multi-paradigm numerical computing setting and exclusive programming language established by MathWorks, was used to plot the results of the ten trials using the plot function in order to better visualize the reaction of the voltage as the distance varies.

Mathematical modelling is the process of using different mathematical structures such as graphs, equations, diagrams, scatterplots, and tree diagrams represent real world situations. The model provides a concept that reduces a problem to its vital characteristics.

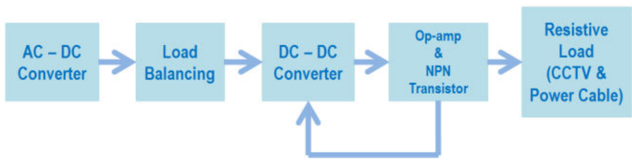

Figure-1. Block Diagram of the system.

The AC-DC converter will convert AC voltage to high DC voltage and low current (24V, 5A) to get the voltage output for an AC-DC converter the V_{peak} or the input AC voltage will be multiplied by 2 and will be divided by n where n is the ratio of the number of turns on the primary and the secondary windings. It will supply the DC-DC converter which will lower the voltage to supply to the load. Afterwards, the sensing circuit which measure the Current feedback from the load to convert it to a signal that will be sent to the controller. If the power supplied to the load is insufficient, the controller will then send a PWM signal to the DC-DC converter that will increase or

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decrease the voltage depending on the signal from the sensing circuit.

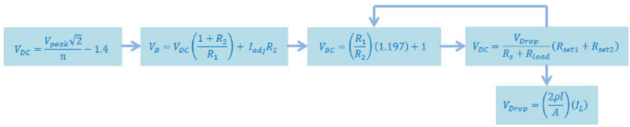

Figure-2. Mathematical Model of the System.

Figure-2 shows the mathematical model that the proponents have come up based on the block diagram that is shown in Figure-3. The mathematical model stated above are per subsystem wherein those equations represent the output including the output of the previous subsystem that became the input of the system.

$$Vdc = \frac{Vpeak\sqrt{2}}{n} - 1.4 \quad (2)$$

$$Vdc = \frac{220\sqrt{2}}{9.16} - 1.4$$

$$Vdc = 32.57\ v$$

$$Vb = (Vdc) * \left(\frac{1+R2}{R1}\right) + Iadj(R2) \quad (3)$$

$$Vb = 32.57 * \left(\frac{1+300}{1000}\right) + (50mA) * (300)$$
$$Vb = 24.795V$$

$$Vbc = \left(\frac{R1}{R2}\right) * (1.197) + 1 \quad (4)$$

$$Vbc = \left(\frac{350000 + 650000}{105000}\right) * (1.197) + 1$$

$$Vbc = 12.4\ v$$
$$Vd = \left(\frac{2pl}{A}\right) * (Iload) \quad (5)$$

$$Vd = \left(\frac{2 * (1.7 * 10^{-8}) * (100)}{(0.0009055)^2}\right) * (0.5A)$$
$$Vd = 2.073V$$

$$Vreg = Iset * (Rset1 + Rset2) \quad (6)$$

$$Rset2 = \left(\frac{Vd}{Imon}\right) \quad (7)$$

$$Vreg = \left(\frac{Vd}{Rs+Rload}\right) * (Rset1 + Rset2) \quad (8)$$
$$Vreg = \left(\frac{2.073}{.02+4.146}\right) * (Rset1 + Rset2)$$

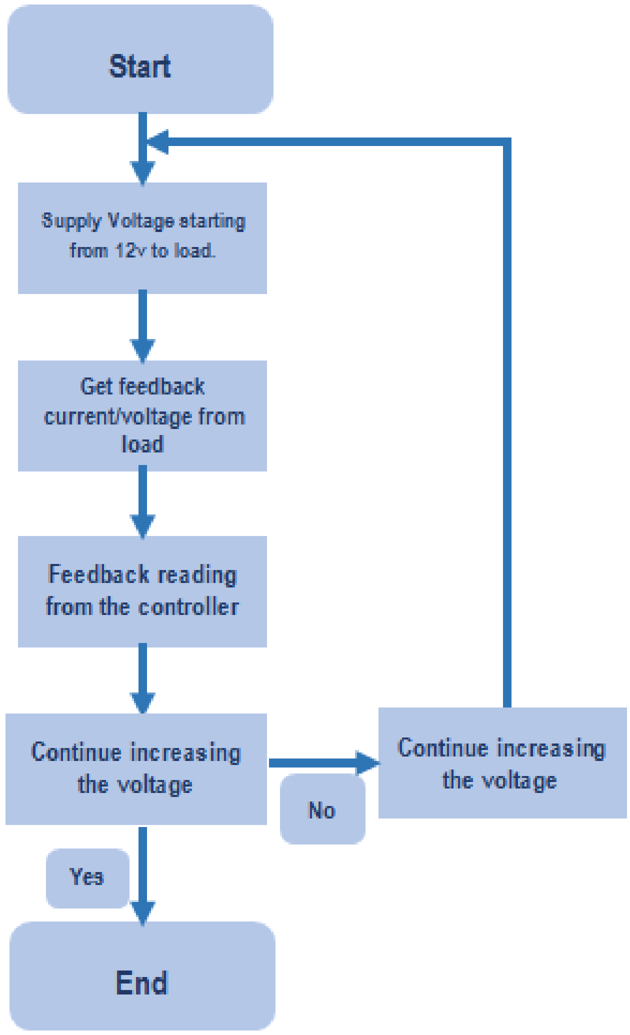

Figure-3. Operation flowchart.

The operation of the proposed circuit is that it will supply 12V to the load(s) and then will receive feedback. The load current will be measured by the current sensor. After the load current was detected and measured it will be converted to a voltage signal that will be readable by the controller of the DC-DC converter. The controller of the DC-DC converter will then adjust the voltage output depending on the feedback from the sensor. If the device detected that the load is receiving less than 12V, the user will then continue to increase the voltage until it reaches the desired 12V.

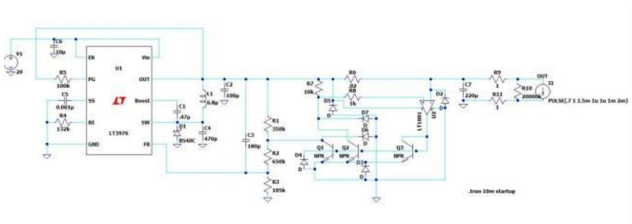

Figure-4. Schematic for cable compensating circuit.

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The circuit is a precision high side current sense with a current mode output, designed for controlling the output voltage of an adjustable power supply or voltage regulator. This can be used to compensate for drops in voltage at a remote load due to resistance in a wire, trace or cable [16].

In Figure-6, since there is no variable resistance a voltage divider network is applied. Keeping the value of R3 constant and varying the value of R6 changes the value of resistance thus, working as a potentiometer. Using 18 AWG as the wire, it is simulated as R7 and R10 in parallel, taking note that 0.020943Ω per meter is used to simulate the distance [17].

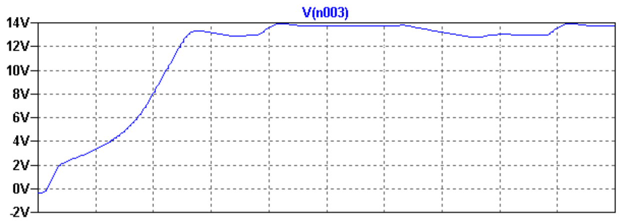

Figure-5. Graph of voltage before the wire.

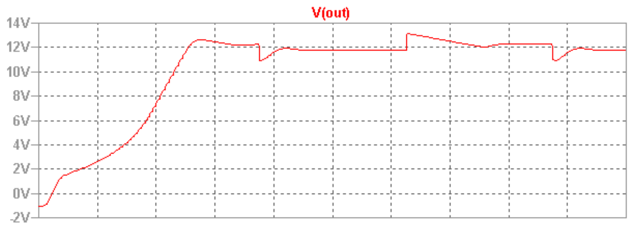

Figure-6. Graph of voltage after the wire.

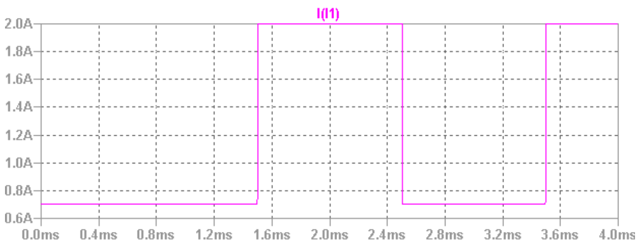

Figure-7. Graph of current after the wire.

Figure-5 is the voltage before the wire with reference to the load current, wherein we see that the voltage being fed to the wire is being adjusted to be able to compensate the voltage loss that happens as the voltage travels the length of the wire, Figure-6 is the voltage being received by the load (CCTV) after it passes through the wire were we see that the voltage is being maintained even though there is a current difference of 1.3 A to display the voltage compensation happening in the wire. The cable compensation circuit monitors the load current via a series-connected internal or external sense resistor. Two current mode outputs, one sinking and one sourcing, are provided that is proportional to the load current.

RESULTS AND DISCUSSIONS

Table-1. Voltage before the wire.

TRIAL	DISTANCE (m)	VOLTAGE (V)
1	25	12.549623
2	50	13.164694
3	75	13.731848
4	100	14.35991
5	125	14.771305
6	150	15.207263
7	175	15.674883
8	200	16.174118
9	225	16.714955
10	250	17.499092

```
>> z = [12.549623 13.164694 13.731848 14.35991
   14.771305 15.207263 15.674883 16.174118
   16.714955 17.499092];
>> y = [25 50 75 100 125 150 175 200 225 250];
>> plot(z,y,'g-.*');grid on;xlabel('Voltage before the
   Wire');ylabel('Distance');
```

Figure-8. MATLAB code for Voltage before the wire.

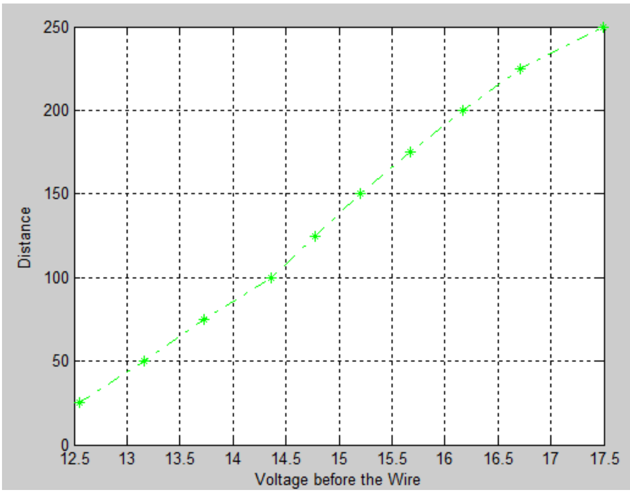

Figure-9. Plot of Voltage before the wire with respect to distance.

The distance increases by 25m every trial. The voltage before the wire is directly proportional as it increases together with the distance to compensate for the loss in the wire as shown in Figure-7.

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Table-2. Voltage after the wire.

TRIAL	DISTANCE (m)	VOLTAGE (V)
1	25	11.985156
2	50	12.002865
3	75	12.010069
4	100	12.025468
5	125	12.065812
6	150	12.110718
7	175	12.15316
8	200	12.161415
9	225	12.263339
10	250	12.265551

```
>> x = [11.985156 12.002865 12.010069 12.025468 12.065812
   12.110718 12.15316 12.161415 12.263339 12.265551];
>> y = [25 50 75 100 125 150 175 200 225 250];
>> plot(x,y,'b--o');grid on;xlabel('Voltage after the
   Wire');ylabel('Distance');
```

Figure-10. MATLAB code for Voltage after the wire.

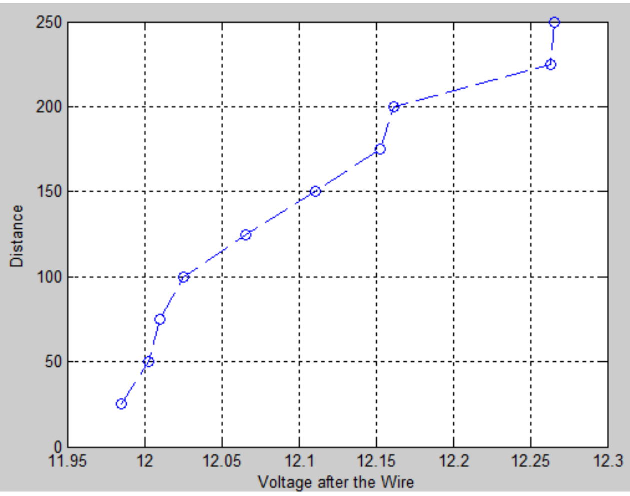

Figure-11. Plot of Voltage after the wire with respect to distance.

There was less than 3% error to the difference of the acquired voltage output and the expected output voltage. The result in Figure-10 clearly shows that as the distance increases, the output voltage after the wire remains constant. The cable consumes a large amount of voltage in which the cable compensation circuit reduces as observed with an increase of approximately 1V in voltage in Table-1 and the output current remaining constant.

CONCLUSIONS

Cable loss is a constant factor that needs to be premeditated when designing a system as it is one of the main causes of the video image quality issues. The expanse of picture quality loss is proportionally associated to the span of the cable.

The cable compensation circuit reduces voltage drop by dynamically adjusting a regulator's output based on load current but it does not necessarily remove the cable loss completely but only minimizes it. Finally, it is inferred that cable length is a major constituent of every digital video such as CCTV and considering the rate at which the technology and safety coincides.

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