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Solar Powered Conveyor Belt System Using Positive Output Super-Lift Converter

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ABSTRACT

The increasing demand for power and considering the downside of fossil fuels, the renewable energy has become an agreeable option. The intermittent availability of renewable power, which is having low voltage levels, has made the boost converters indispensable. A standalone PV system is used to power load using a high step-up Positive Output Super-Lift Luo (POSLL) Converter. POSLL converter is used for this conversion, as it satisfies wide range of output voltage with high power density and low inrush current. Solar energy is a clean energy source which does not pollute the environment. The PV module feeds power to the system using a DC-DC converter (POSLL Converter). The Maximum Power Point Tracking (MPPT) control technique has been used for the PV system to track the maximum power. The Perturb and Observe (P&O) algorithm is used for the maximum power extraction. Voltage control has been done using PI and ANFIS controllers separately. On comparing the output power gained from both controllers, ANFIS is better. This standalone system is very beneficial for places where supply to grid connection is less feasible.

I. Introduction

In this growing population and increasing modernization, global energy demand is more than double the expectation. Now-a-days fossil fuel usage is getting down due to its serious impacts like climatic change. In addition to that the fuels, we are using now is not renewable in nature. So, the supply is limited. Thus in future, the technologies will be depending on Renewable resources. The recent research and technologies are motivated towards the naturally occurring Renewable Energy which offer viable solution to meet our global energy challenges. The major downside which revolves around fossil fuel is compensated in renewable resources. Solar is one of the vital sources in renewable energy. The large magnitude of solar energy available makes it a highly appealing source of electricity. Active solar techniques include the use of photovoltaic silicon panels. The power variation is monitored by the Maximum Power Point Tracking (MPPT) system, using Perturb and Observe (P&O) method.

The DC-DC conversion technique was established in 1920's. The simplest form of conversion is using voltage divider. One of the converters which is used to run DC motor is Positive Output Super-lift Luo (POSLL) Converter which is based on the voltage-lift technique. Luo converters differ in the sense of constructional architecture which has a dual active switch. The Positive Output of Super-lift Luo converter is a new series of DC-DC converter possessing high-voltage transfer gain, high power density, high efficiency, reduced ripple voltage and ripple current. These converters are widely used in peripheral equipment, industrial applications, etc.,

II. Approach

2.1 PV SYSTEM

The photovoltaic cell directly captures the light rays from the sun, which converts those rays into electricity using photoelectric effect. This method of conversion is pollution free. The photovoltaic panel consists of series of photovoltaic cells, which are fabricated using MEMS technologies. Basically, this cell consists of two layers- positive and negative layer.When the PV cell is exposed to sunlight, the semiconductor atoms absorbs the photons and the free electrons flows from negative to positive layer through an external circuit, producing Direct Current (DC).

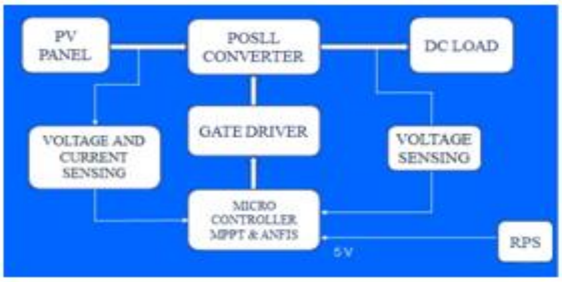

Fig 2.1 a. Simple block diagram.

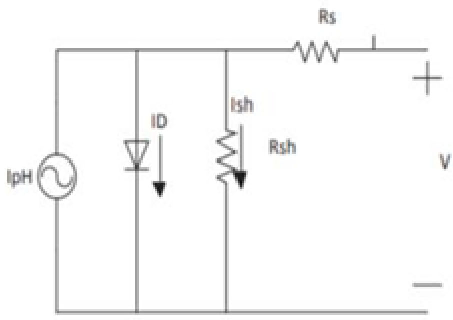

Fig 2.1 b. Equivalent circuit of PV System.

$$P_{max} = \gamma V_{max} I_{max}$$
$$P_{max} = V_{oc} I_{max}$$
$$I = I_{ph} - I_d - I_{sh}$$

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$$I_d = I_0\left[e^{\left(V/_{AVTN_s}\right)} - 1\right]$$
$$VT = \frac{kTc}{q}$$

Tc is the PV cell temperature (K), k is the Boltzmann constant of 1.381* 10^23J/K, q is the electron charge (1.602*10^19 C). VT is the thermal voltage because of its exclusive dependence of temperature. Ns PV connected solar cells, A is the PV cell technology dependent on ideality factor.

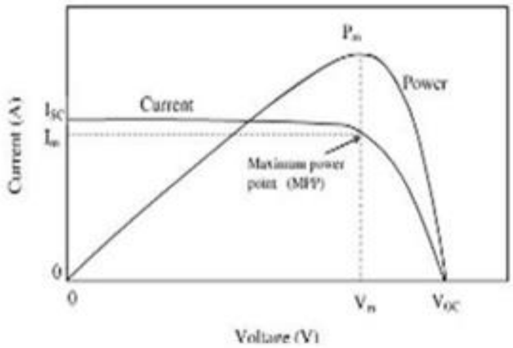

Fig 2.1c. MPPT P-V Characteristics.

2.2 Maximum Power Point Tracking (MPPT)

Maximum Power Point Tracking (MPPT) is an algorithm implemented in photovoltaic (PV) cells to continuously adjust the impedance seen by the solar array to keep the PV system operating at, or close to, the peak power point of the PV panel under varying conditions, like changing solar irradiance, temperature, and load. Usually MPPT algorithms are used to track the maximum power generated by PV systems. The algorithms control the voltage to ensure that the system operates at "Maximum Power Point" on the power voltage curve.

MPPT system, has many techniques such as:

i. Perturb and Observe (P&O)
ii. Incremental Conductance method (INC)
iii. Fractional Short Circuit Current (FSCC)
iv. Fractional Open Circuit Current (FOCC)
v. Artificial Neural Networks (ANN)
vi. Fuzzy Logic (FL)
vii. Neuro Fuzzy Logic

Perturb & Observe technique is utilized for its time complexity and simple algorithm.

2.2.1 Perturb and Observe Method (P&O)

This P&O method is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and fall above that point.

This is an iterative method. It continuously tracks the power in the solar panel and compares the output power of solar panel with the previous power. The difference (ΔP_{pv}) in the output power is absorbed. It keeps on updating the maximum power. If ΔPpv is positive, the perturbation of the operating voltage should be in the same direction of the increment. If it is negative, the system operating point obtained moves away from the MPPT and the operating voltage should be in the opposite direction of the increment, perturbation should be reversed to move back towards the MPP. This process continues till dPpv/dVpv=0 regardless of the irradiance and the PV module's terminal voltage.

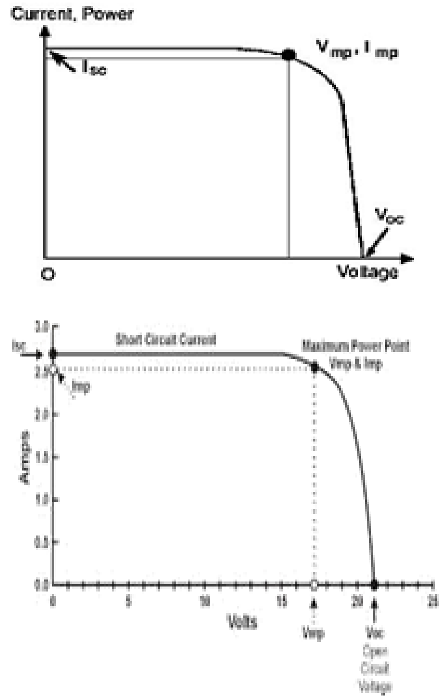

Fig 2.2.1b. I-V and P-V characteristics.

The flow of P&O algorithm by which the PV system's output voltage and output current are tracked is shown in the Fig 2.2.1(c).

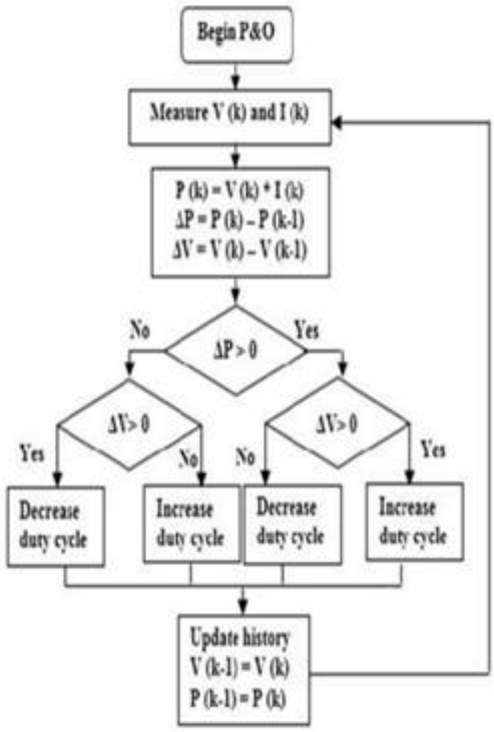

Fig 2.2.1c. Perturb & Observe Method(MPPT)

Among the various MPPT algorithms, P&O is simple and it is ease in implementation.

2.3 Super-Lift Luo Converters

Voltage lift (VL) technique has been successfully employed in design of DC/ DC converters, e.g., three series Luo-converters. However, the output voltage increases in arithmetic progression. Super-Lift (SL) technique is more powerful than VL technique, its voltage transfer gain can be a very large number. SL technique implements the output voltage increasing in geometric progression. It effectively enhances the voltage transfer gain in power series.

The Super-Lift Luo Converters are widely classified into four series. They are:

[1] Positive Output Super-Lift Luo Converters
[2] Negative Output Super-Lift Luo Converters
[3] Positive Output Cascade Boost Converters
[4] Negative Output Cascade Boost Converters

Among these four, we have taken Positive Output Super-Lift Luo Converters for the voltage amplification process.

2.3.1positive Output Super-Lift Luo Converter

In this converter, the conversion is from positive voltage to positive boosted voltage.

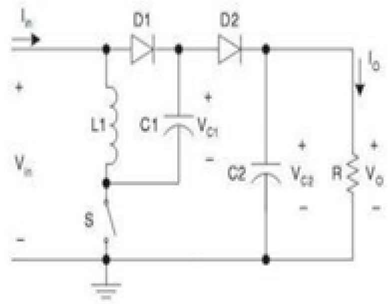

Fig 2.3.1 a. Elementary Circuit.

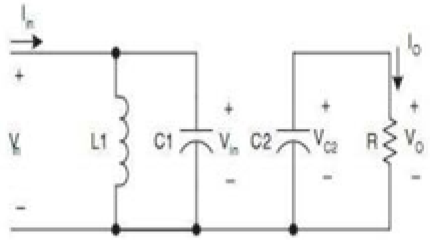

Fig 2.3.1 b. Mode1: SWITCH ON.

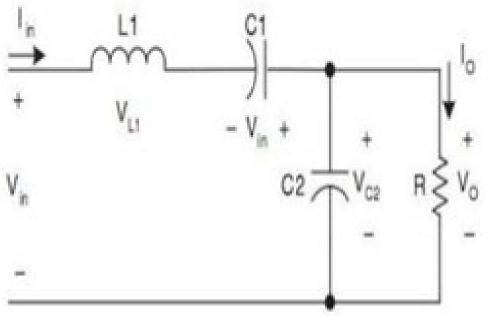

Fig 2.3.1c. Mode2: SWITCH OFF.

The elementary circuit and its equivalent circuits during switch ON and OFF conditions shown in the Fig 2.3.1. The voltage across capacitor C_1 is charged to V_{in}. The current I_{L1}, flowing through the inductor L_1 increases with voltage switch OFF period (1-k) T.

The ripple voltage is:

$$\Delta i_{L1} = \frac{V_{in}}{L_i} KT \quad \text{..........} \quad (1)$$

$$\Delta i_{L1} = (V_0 - 2V_{in})(1-k)\,T/L_1$$

$$V_0 = \frac{(2-k)}{1-k} V_{in} \quad \text{............} \quad (2)$$

Voltage transfer gain is,

$$G = \frac{V_0}{V_{in}}$$

$$G = \frac{2-k}{1-k} \quad \text{..........} \quad (3)$$

The input current i_{in} is equal to (i_{L1} + i_{C1}) during switching-on and only equal to i_{L1} during switching-off. Capacitor current i_{C1} is equal to i_{L1} during switching-off. In steady-state, average charge across capacitor C should no charge. Following relations are obtained.

$$i_{LR-off} = i_{L1-off} = i_{C1-off}$$

$$i_{in-on} = i_{L1-on} + i_{C1-on}$$

$$kTi_{C1-on} = (1-k)Ti_{C1-off}$$

Inductance L_1 is large enough, i_{L1} is nearly equal to its average current. Therefore,

$$i_{in-off} = i_{C1-off} = I_{L1}$$

$$i_{in-on} = i_{L1} + \frac{1-k}{k} I_{L1} = \frac{I_{L1}}{k}$$

$$i_{C1-on} = \frac{(1-k)}{k} = I_{L1}$$

And average output current,

$$i_{in} = ki_{in-on} + (1-k)i_{in-off} = I_{L1} + (1-k)I_{L1} = (2-k)I_{L1} \quad \text{...............} \quad (4)$$

Considering,

$$\frac{V_{in}}{I_{in}} = \left(\frac{1-k}{2-k}\right)^2 \frac{V_0}{I_0} = \left(\frac{1-k}{2-k}\right)^2 R \quad \text{.............} \quad (5)$$

The variation ratio of current iL_1 through inductor L_1 is,

$$\xi_1 = \frac{\Delta i_{L1}/2}{I_{L1}} = \frac{k(2-k)TV_{in}}{2L_1 I_{in}} = \frac{k(1-k)^2}{2(2-k)} \frac{R}{fL_1} \quad \text{...........(6)}$$

Usually €1 is small (much lower than unity); it means this converter normally works in the continuous mode.

The ripple voltage of output voltage V_0 is,

$$\Delta V_0 = \frac{\Delta Q}{C_2} = \frac{I_0 kT}{C_2} = \frac{k}{fC_2}\frac{V_0}{R} \quad \text{...............} \quad (7)$$

Therefore, the variation ratio of output voltage V_0 is,

$$\varepsilon = \frac{\Delta v_0/2}{V_0} = \frac{k}{2RfC_2} \quad \text{..............} \quad (8)$$

Usually R is in kΩ, f in 10 kHz and C_2 in μF, this ripple is very smaller than 1%.

III. Control System

The non-linear output voltage of DC-DC converters is a problem with serious concern.Combined with the intermittent nature of renewable solar energy source, it enhances the dynamic behaviour of the system. The PI controller is one of the basic controllers which are used in dc-dc converters , but the non-linearity is not completely eradicated using PI controller. On the other hand, the Adaptive Neuro Fuzzy Inference(ANFIS) controller can train the data and also make decision which is a specialised feature.

Since the ANFIS employs , neural training the output obtained from this is more accurate than the output obtained from PI controller. The closed loop of positive output superlift converter has been done with both PI controller and ANFIS controller and the output voltage of both have been compared in this paper and the resulting waveforms are included.

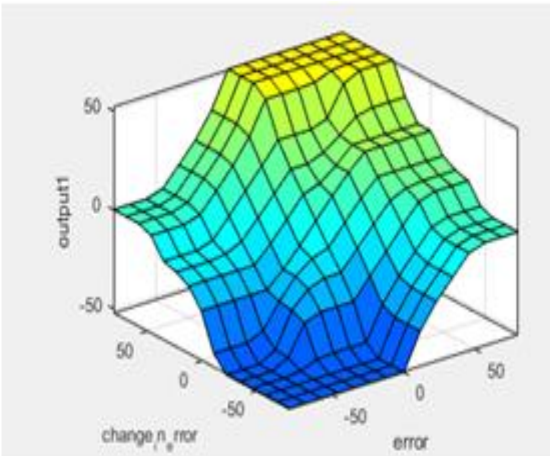

Fig 3.1. Rule Base surface view.

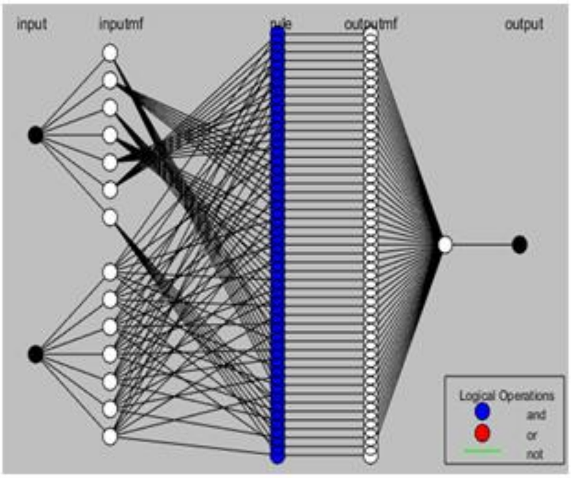

Fig 3.2. ANFIS Structure.

IV. Simulation

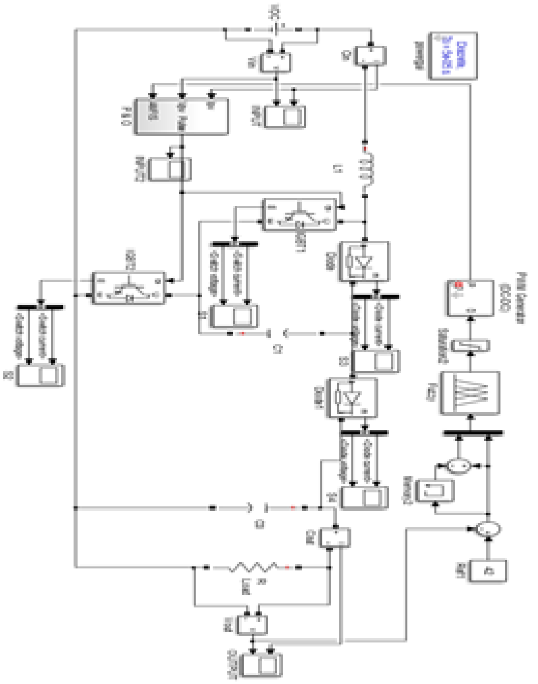

Fig 4.1. MATLAB/Simulink model of POSLLC with ANFIS.

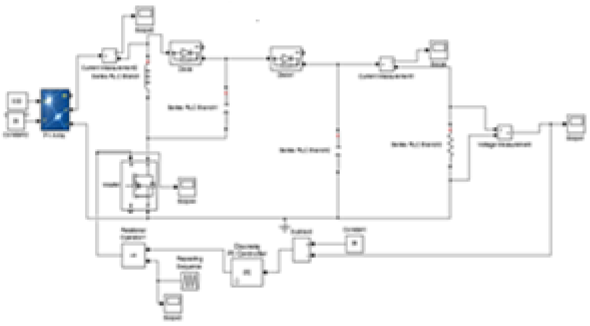

Fig 4.2. MATLAB/Simulink model of POSLLC with PI.

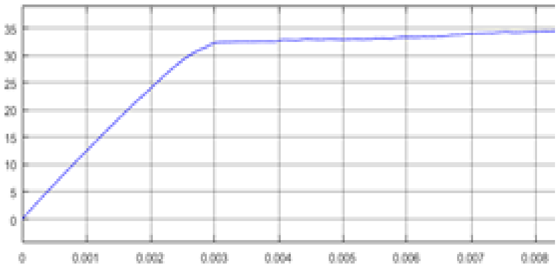

Fig 4.3. Output Voltage of POSLL Converter with PI.

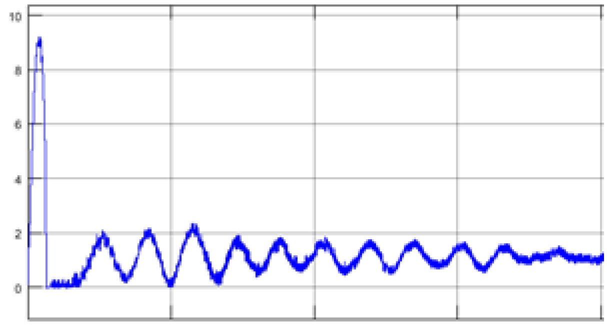

Fig 4.4.1. Input Current of POSLL Converter .

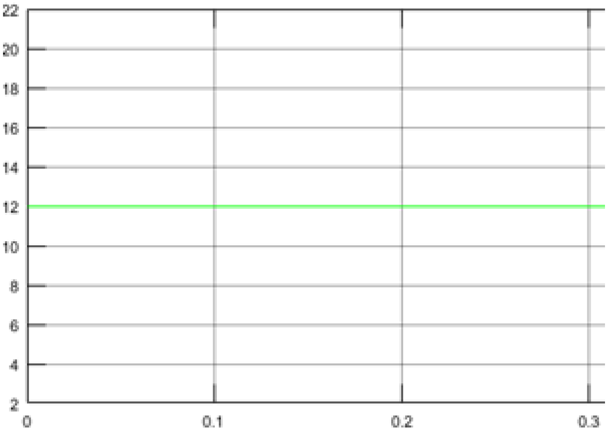

Fig 4.4.2. Input Voltage of POSLL Converter.

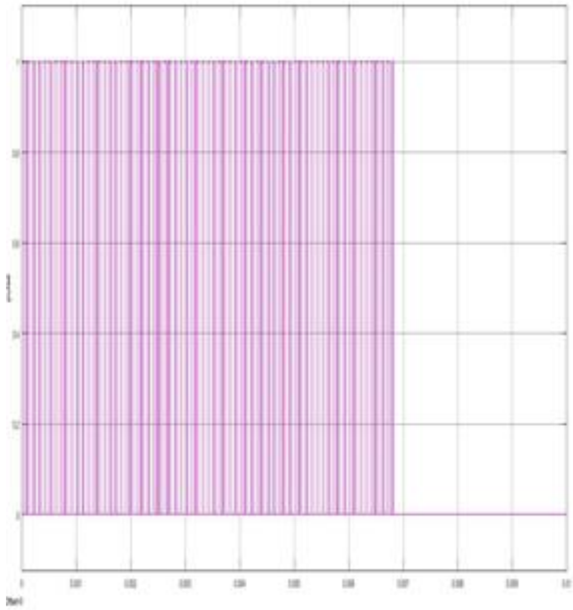

Fig 4.5. Gate Pulse of Positive Output Super-Lift Converter.

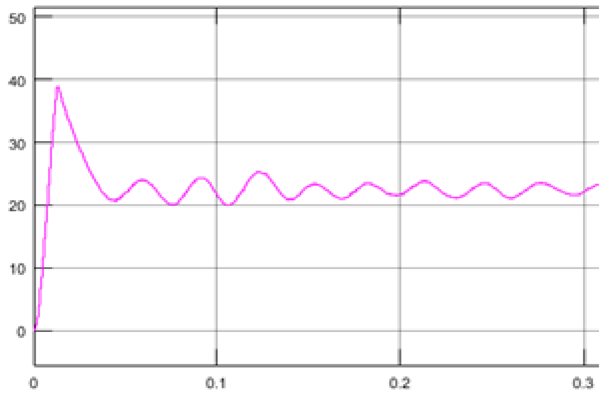

Fig 4.6. Output Voltage of POSLL Converter with ANFIS.

V. Application

The boosted power gained from the POSLL converter is utilized here to run the conveyor belt systems. The belt conveyor technology has been used in conveyor transport such as moving sidewalks or escalators, and in many manufacturing assembly lines. Industrial and manufacturing applications for belt conveyors include package handling, trough belt conveyors, trash handling, laundry service stores and more. Apart from running the conveyor belts, the gained power can be utilized in many ways. By converting the DC power to AC using an inverter and through synchronization we can connect it to the grid. It can also be used to run irrigation motors, battery chargeable vehicles, solar powered lights like GUARDIAN 580X, IVYSHION, DENEVE Solar Flagpole Light and so on.

VI. Conclusion

The closed loop simulation of Solar Powered Conveyor Belt System using Positive Output of Super-lift Luo Converter was successfully carried out using both ANFIS and PI Controller in MATLAB/Simulink Software and when the output waveforms are observed, for an input voltage of 12V , the output voltage of 35V has been obtained with PI controller and 36 V has been obtained with ANFIS. The Output voltage of Super-lift Luo Converter reaches the desired level of voltage faster than conventional boost converter. This is one of the advantage factors in selecting Super-lift Luo Converter. The POSLL Converter employs the Super-lift technique to obtain boosted Output voltage. Here the voltage rise will be in geometric progression.

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