Regulation of the Extracted Energy Induced in Shield Wires of an HV Transmission Line

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Abstract- **It is necessary to have constantly operational monitoring systems which uses electric powered devices for transmission of electricity over high voltage transmission lines. This paper investigates a source of power to feed these ancillary service loads since the conventional power supply systems are infeasible. The voltage induced in the shield wires of an HV transmission line is tapped off, regulated and used as a power source. We use a dc-dc converter inorder to get a regulated dc output. The results obtained shows a feasible and cost effective alternative for power source.**

1. INTRODUCTION

In recent years, the ancillary service loads has increased in number by a large amount which require low-power dc voltage supplies. This is the case of some warning lights, surveillance cameras, line inspection robots, small weather stations and other monitoring devices. The earlier used power supply systems were : photo voltaic panels and use of dedicated low voltage line. These had a lot of disadvantages and so we go for the new method .The use of LV line due to technical and economical issues is unfeasible and the second option is bulky, weather dependent, requires additional energy storage system (battery).

These problems can be overcome by obtaining energy from the shield wires of EHV transmission lines. The use of tap-off power from shield wires has been put forward many years ago [2].Energy is induced in these shield wires as a result of induction effects. The shield wire has the purpose to protect the phase conductors and is never used for energy transmission. We have to insulate this wire inorder to tap off the energy from it.

2.ANCILLARY SERVICE LOADS

Warning lights, surveillance cameras, line inspection robots, small weather stations, cathodic protection systems on metallic tower foundations and other monitoring devices constitute the ancillary service loads depicted in Fig.1,Fig.2, Fig.3.

The microwave repeater stations located in remote areas could be fed from tapped power from a shield wire and is describe in [3]. [4] proposes the transmission line inspection robot fed through an induction system from shield wires.
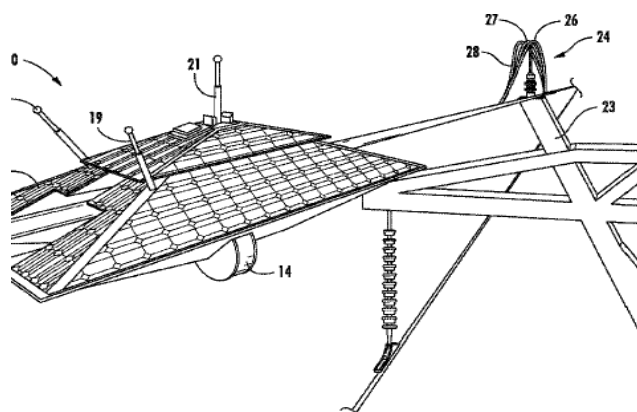

Fig.1 Warning lights

Fig.2 Line inspection robots

Fig.3 Surviellance cameras

3. INDUCTION EFFECTS

When a shield cable is installed near very high-voltage transmission lines voltage is induced in it by either electrostatic induction or electromagnetic induction. The induction mechanism is broadly classified into electromagnetic induction and electrostatic induction. The characteristics of electrostatic and electromagnetic induction generated by HV transmission lines are described in [5]. Reference [6] presents a study related to induced voltages produced by the electric field induction. The generation mechanisms are illustrated in Fig.4

Electrostatic induction is caused by a high voltage in an electric power transmission line or other such sources. Electrostatic capacitance C1 exists between the electric power transmission line and the shield wire. Electrostatic capacitance C2 also exists between the shield cable and earth. These electrostatic capacitances lead to the voltage dividing of the alternating current voltage Vo, and then electrostatic induction voltage Vs arises between the shield wire and earth.

Electromagnetic induction, on the other hand, is caused by the current flowing in the electric power transmission line or other such source. The alternating current in the electric power transmission line, Io, induces a time-varying magnetic field around the electric power transmission line. As the magnetic field gives rise to the induced current Ie that flows to prevent the magnetic field from varying in the electric power cable, the electromagnetic induction voltage Ve is also generated in the shield wire.

Calculation methodologies to obtain the equivalent circuit parameters from a transmission-line capacitive effect for tap-off power using ground wires can be found in [7] and [8]. In [9], a method to reduce the induced power losses in the ground wires is presented.
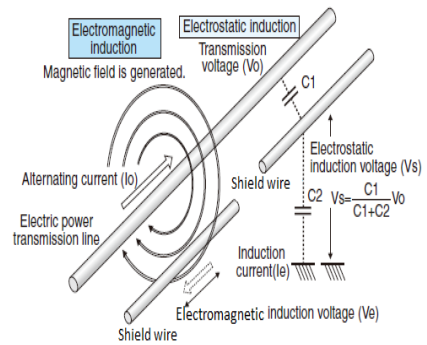

Fig. 4 Contribution of electrostatic and electromagnetic induction effect for tap-off power.
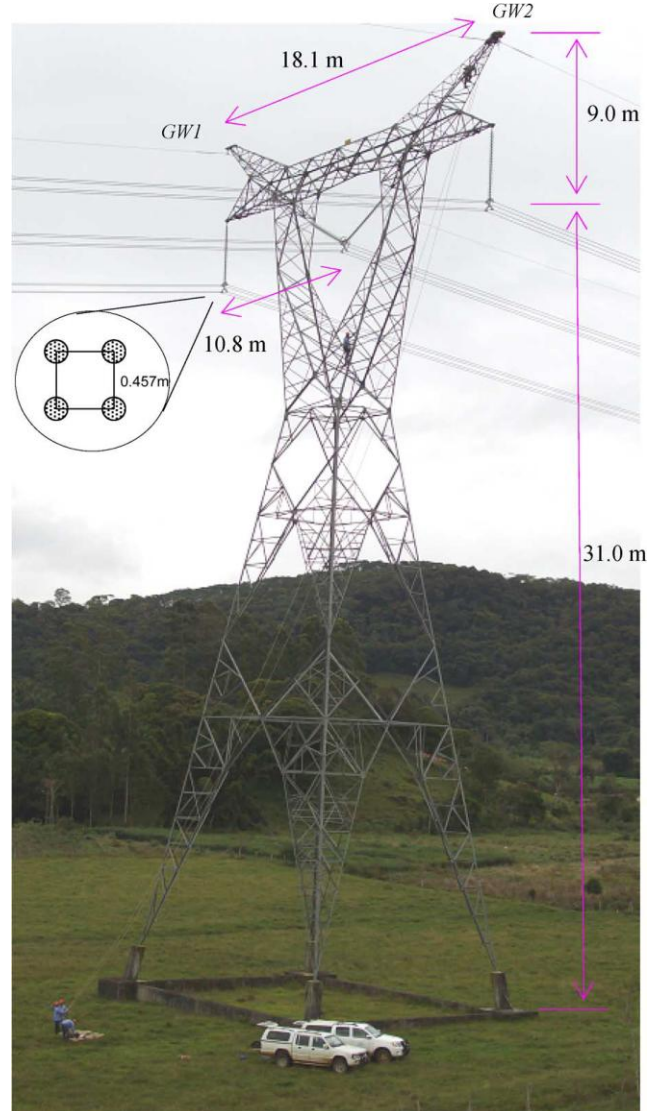
4.TOWER CONFIGYRATION

Fig.5 Transmission tower characteristics

Simulation tests are performed on 525 kV transmission line. Tower configuration is depicted in Fig.5. It has phase conductors arranged in a quadruple bundle configuration and there are two ground wires used at the two edges of the tower.

4.SHIELD WIRE CIRCUIT CONFIGURATION

There exist two circuit configurations. The shield wire configuration that produces highest tap-off power is of our importance. The two configurations are :1)use of only one shield wire 2)two shield wires connected forming a loop. In the first configuration both the shield wires works independently with earth as return path as depicted in Fig 6(a).second configuration is depicted in Fig.6(b),which has the profit of induction of both wires. For the tower configuration as in Fig.5 the current direction in each independent shield wires is opposite; hence the loop arrangement is adopted.
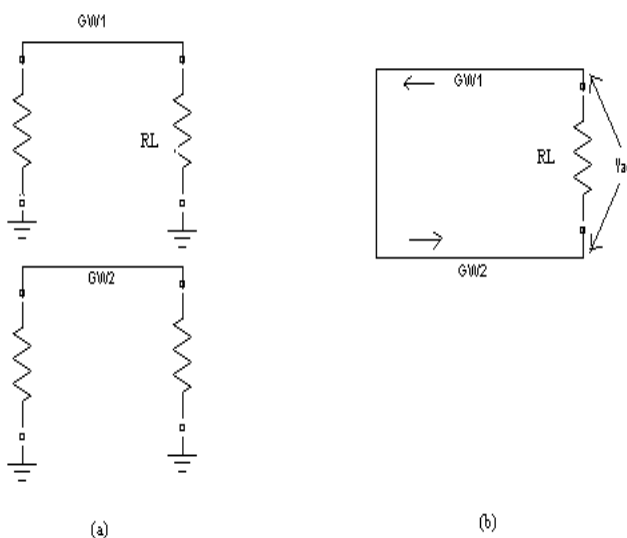

Fig.6. (a) Ground wires considered independently. (b)Loop connection.

5.BLOCK DIAGRAM

Block diagram is depicted in Fig.7. Since the phase current variations throughout the day affect the induced voltage in the overhead ground wire, a step-down dc-dc converter is used after rectification of ac voltage to provide a regulated dc output voltage. We usually go for buck converter that produces a dc voltage less than the input voltage. The switching device is chosen as MOSFET. For the present application the duty cycle (D) of dc-dc converter will be set at low value, during the periods of high induction effect on the ground wires. The converter operates at 40 kHz in the continuous current mode.

The output voltage is regulated by a closed-loop voltage-mode control method. We set a reference voltage value according to the application requirement. The output voltage

is continuously measured and compared against this specified reference voltage. Thus any voltage variation occurring at the input will be automatically regulated and tied to specified reference voltage.
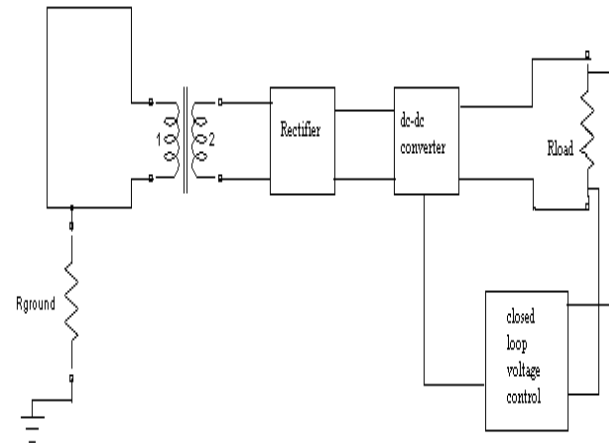

Fig.7. Block diagram representation.

6.SIMULATION DETAILS

Simulation is done in PSCAD software. Fig.8 shows complete system implemented. Bergeron transmission model is used. The soil resistivity and tower foot resistance considered in simulations are 1000Ω and $20\ \Omega$ respectively. Load resistance equals 3 Ω. Fig.9,10,11 shows the behavior of D, V_O, I_O, V_{ac}

V_{ac} , I_{ac}: induced parameters measured at the transformer input terminals;

V_O , I_O: dc–dc converter output parameters;

P_{ac}: power at the input of the transformer;

P_{dc}: power at the output of the dc–dc converter;

η: efficiency of the overall system.

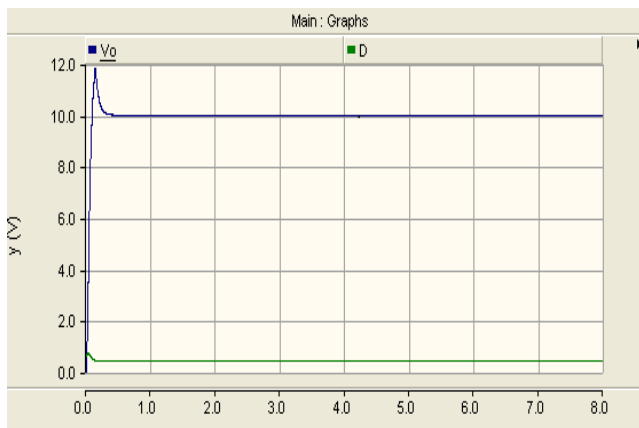Fig. 8 Complete system implemented in PSCAD.

Fig.9 Voltage output and duty cycle.
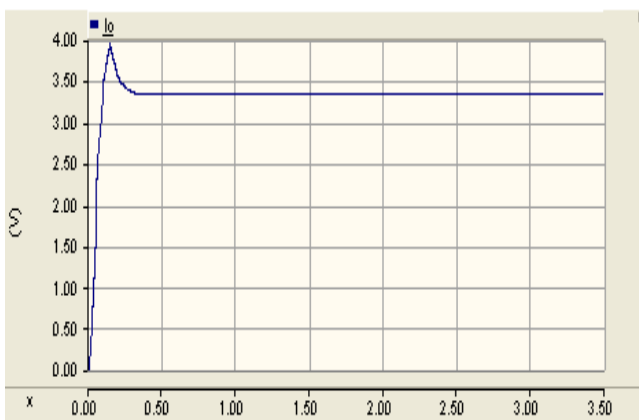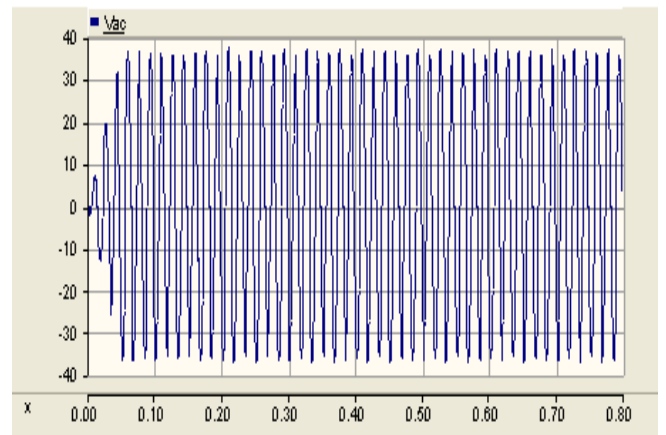

Fig. 10 Output current waveform

Fig. 11 Voltage at the primary of transformer.

7.ADVANTAGES AND APPLICATIONS

The low power source presented herein gives a regulated output voltage, does not depend on weather conditions, allows the replacement of the energy storage devices without energy interruption, and can be used in remote areas with difficult access. It is cost effective alternative and is feasible.

Apart from the applications mentioned in section 1 several other uses of the tap-off power can be performed in real transmission lines. To mention some of them surveillance cameras, inspection robots, line sag sensors, conductor temperature sensors are devices that require low power dc supply for their operation.

8.CONCLUSION

It gives the best method to feed the small ancillary service loads. The PI controller implemented herein regulates the output voltage to the set reference voltage value. It is proved to be effective while maintaining the dc output voltage of the tap-off system constsnt.

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