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A Study on Energy Harvesting from Sub Transmission System to Power Wireless Sensor Nodes

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***Abstract*—Renewable Energy Harvesting to power sensor nodes has been a very sensitive issue of discussion in recent years. With the emerging MEMS(Micro Electro-Mechanical Systems) Technology, the wireless sensor nodes have gained wide importance and the process involved in continuous powering of these nodes is also challenging. The supply to the sensor nodes as applied to the monitoring of A C Transmission lines needs to be addressed separately other than the battery technology. This paper presents the Simulink model to measure the magnetic flux that can be extracted from the Sub-transmission system i.e., 33KV, 66KV, 132KV and 220KV and the simulation results are quiet promising to power up the sensor nodes.**

***Index Terms*— Magnetic Flux, SubTransmission System, WSN, Simulink Model.**

I. INTRODUCTION

The sub transmission line which are usually out of sight have to be monitored carefully since 85-87% of power system faults are occurring in transmission lines [1]. The critical states of a transmission line like sag of conductor due to temperature variation, icing, aging, line breakage are monitored online through condition monitoring [2]. WSN's have provided solutions to variety of problems and supply to these sensor nodes is one of the major issues to be solved. The different forms of energy harvesting possible through solar, mechanical, fluid, acoustic, magnetic and hybrid energies are briefed by the authors of [3] through their reviews. In this paper we concentrate on magnetic energy harvesting in sub transmission system to power sensor nodes which are employed in monitoring different conditions of A.C Transmission lines. Harvesting of energy radiated from power lines is feasible according to the authors of [4]. This has been further taken ahead to measure the amount of magnetic energy that can be scavenged from 33kv, 66kv, 132kv and 220kv lines in this paper. The deployment of sensors in the field should be self organising which is the challenge for next generation [5]. The authors of paper [2] have proposed an energy harvester tube for a single line carrying current of 190A. The harvester encloses the line in circular fashion. The conventional methods for energy harvesting from power lines makes use of current transformers. An independent permanent magnet synchronous generator for AC Transmission lines is proposed by the authors of [6]. However the arrangement seems to be complex and costlier. A free standing inductive harvester concept has been dealt in

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paper [7], but the exact location and its implications are not suffice except for the placement of such a system at the substation level. The authors of paper [8] discuss the opportunities and design challenges of WSN's and has concluded that energy harvesting for most sensor node has wide acceptance and is the emerging technology of the era. The author also mentions that the lifetime of the node depends on the lifetime of the battery and renewable means are at its highest scope to keep the node active. The magnetic flux density measurement under the 400kv line is measured to be around 6μTrms with a measurement height of 1m above the ground[9]. The author suggests to use the average value of magnetic flux density for any line under consideration. In case the harvested energy from magnetic field is insufficient for the sensor network, the voltage doubling rectifier circuit for wireless sensor network has been proposed by the authors of [10]. According to [11] nearly 250mw of power is sufficient to power up a sensor node. This paper proposes a magnetic flux extraction scheme under 33kv, 66kv, 132kv and 220kv which has been successfully simulated and we see that the amount of power that can be extracted from these lines is sufficient to power up sensor nodes and in case of fluctuations in the amount of power drawn from these lines a suitable arrangement of battery for storage purpose can also be done.

II. Measurement of magnetic flux

When current flows through a transmission line magnetic flux is produced that surrounds the line conductors. With high voltage sources huge current flows and the intensity of magnetic flux increases with increase in current as given by the equations (1) and (2)

$$\oint c \;\; H \, dl = I \qquad (1)$$

$$B = \mu H \qquad (2)$$

The 33kv, 66kv, 132kv and 220kv transmission lines are simulated for magnetic flux density as depicted in the figures 1.1, 1.2, 1.3 and 1.4 .

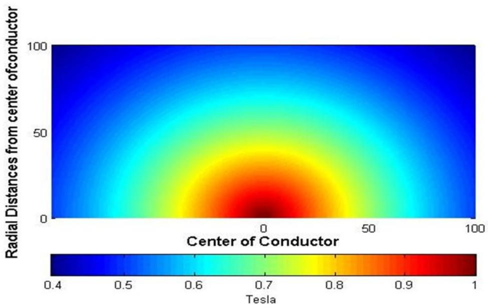

Figure 1.1 Magnetic flux around 33kv line

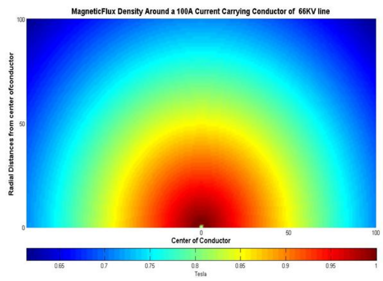

Figure 1.2 Magnetic flux around 66kv line

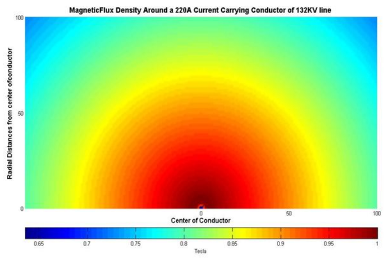

Figure 1.3 Magnetic flux around 132kv line

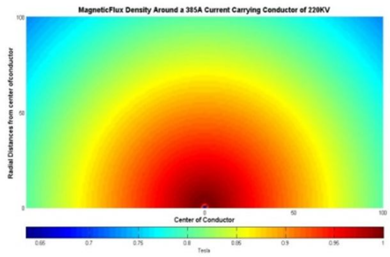

Figure 1.4 Magnetic flux around 220kv line

The 33kv line is considered for 100A and 100m length. It can be observed that magnetic flux is maximum at the center of the conductor (shown in dark red color) and goes on reducing as the distance increases. The useful flux is limited to 0.4T(shown in dark blue color). The 66kv Transmission line is considered for 100A and 200m length and the useful flux is limited to 0.65T. The 132kv transmission line considered for 220A and 300m length, has useful flux limited to 0.75T. The 220kv transmission line is considered for 385A and the length of the conductor is 300m.The limited flux is 0.83T. As observed the intensity of useful flux increases with increase in transmission voltage and current.

The 33kv, 66kv, 132kv and 220kv transmission lines are also modelled in Simulink for flux generation as in figure 1.5 and the simulation results are as shown in figure 1.6. A comparative study of flux generation with MATLAB and SIMULINK is shown in table 1.1.

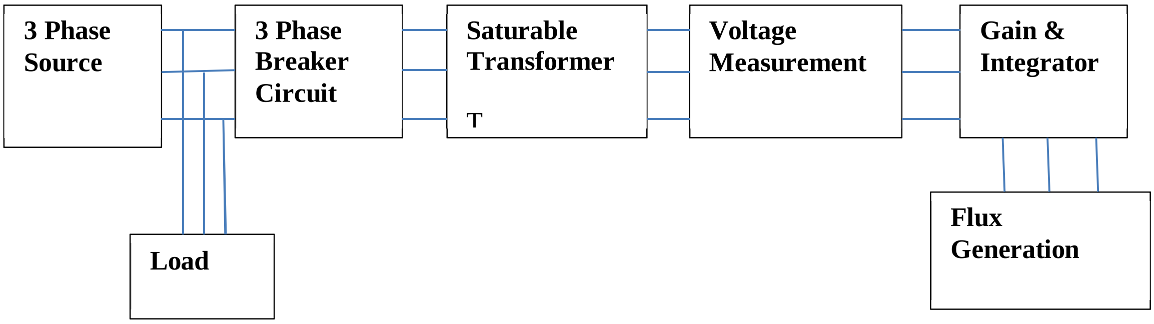

Figure 1.5 Simulink model for flux generation

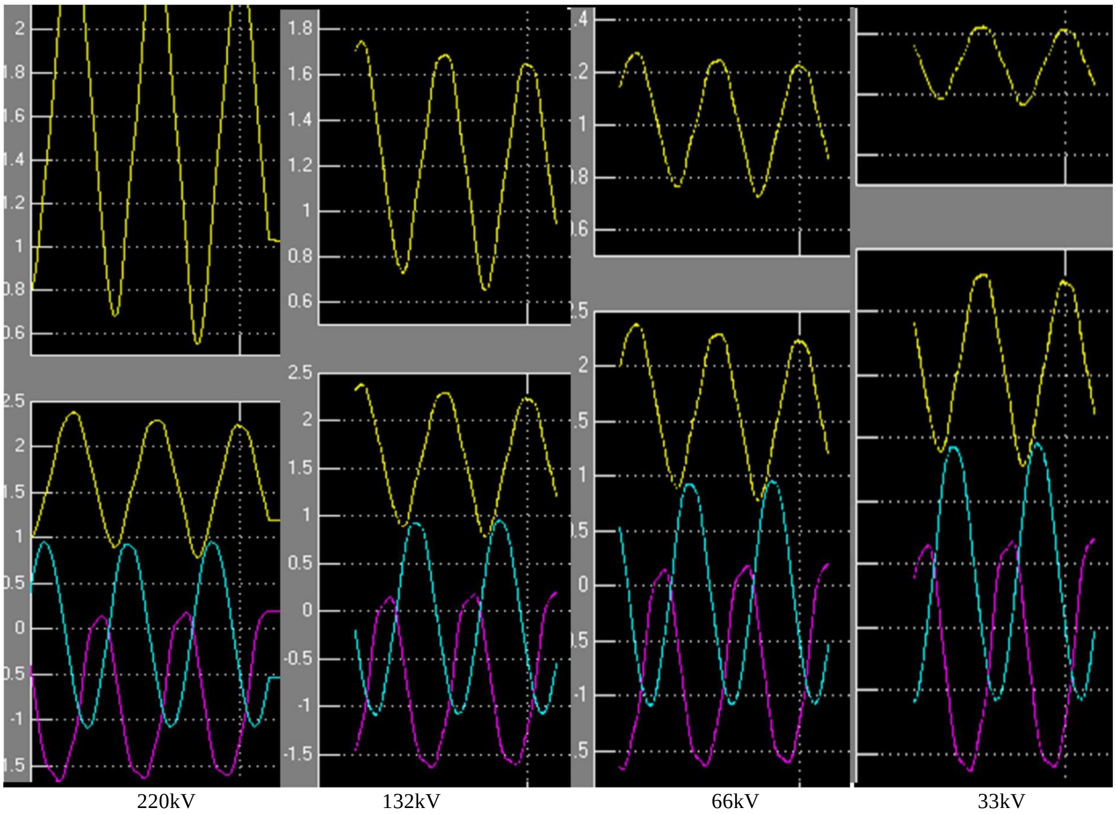

Figure 1.6: Simulation results of flux generated for 33kv, 66kv, 132kv and 220kv transmission line

TABLE 1.1 COMPARISON OF SIMULATION RESULTS OF MEASUREMENT OF MAGNETIC FLUX WITH MATLAB

Sl No	Transmission Line Voltage	Measured value of Magnetic Flux in Tesla	
		MATLAB	SIMULINK
1	33kV	0.4 – 1	0.8 - 1
2	66kV	0.65 – 1	0.8 – 1.2
3	132kV	0.75 – 1	0.8 – 1.65
4	220kV	0.83 – 1	0.6 – 2.3

The comparative study shows that the magnetic flux generated is less in MATLAB as compared to Simulink which is because of the limited radial distance from the center of the conductor to 100m, elseworth the results are relatively same.

III. MODELLING OF ENERGY HARVESTER

The Block Diagram for energy harvesting and its Simulink Model is as shown in figure 2.1 and 2.2. For different voltage sources, the flux surrounding the line is harvested for getting an output voltage with the help of a current transformer whose output is given to a bridge rectifier for rectification purpose and the outputs are as depicted in figures 2.3, 2.4, 2.5 and 2.6. A capacitor filter is used to get DC output which is then regulated using a zener diode.

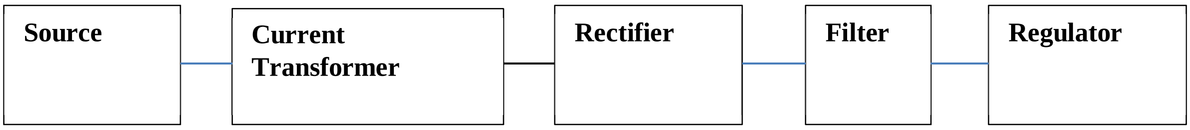

Figure 2.1: Block Diagram for Energy Harvesting

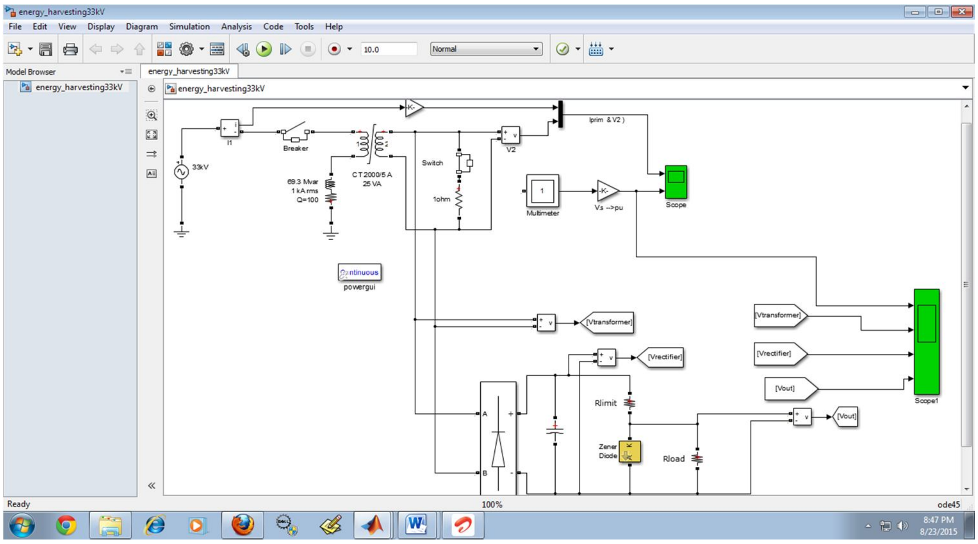

Figure 2.2: Model for Energy Harvesting in Simulink

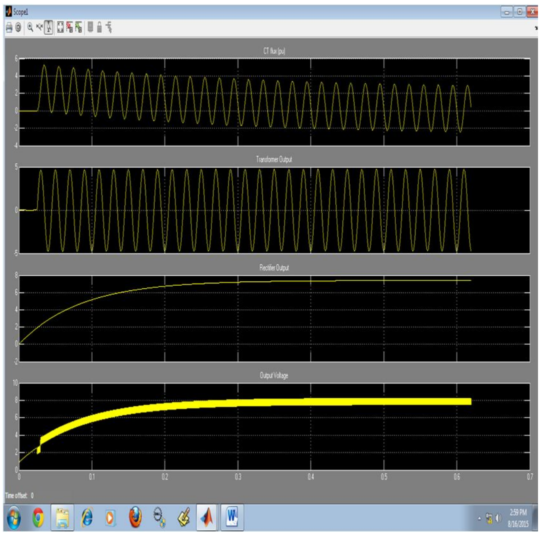

Fig 2.3 Flux and voltage output considering 33kv source voltage

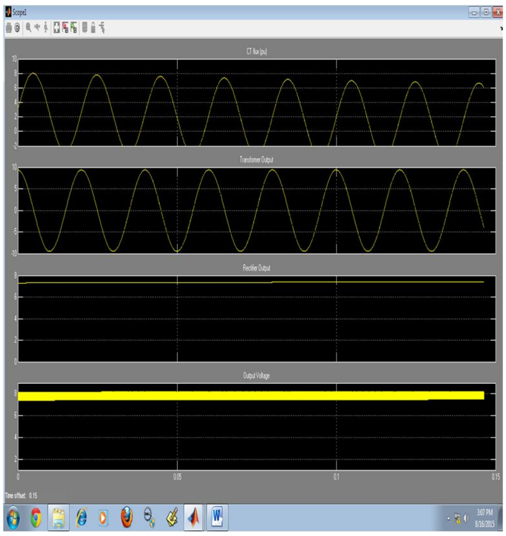

Fig 2.4 Flux and voltage output considering 66kv source voltage

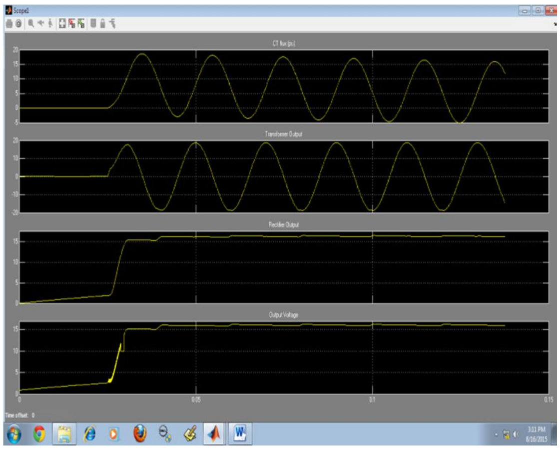

Fig 2.5 Flux and voltage output considering 132kv source voltage

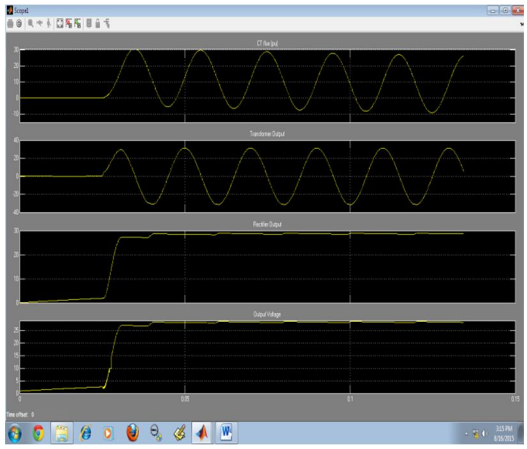

Fig 2.6 Flux and voltage output considering 220kv source voltage

The power drawn from the extracted magnetic energy from different voltage sources are summarized in table 2.1. From the table we can infer that the harvested energy is sufficient to power up sensors and a balance must be achieved in order to keep all nodes active all time for which we can make use of storage batteries.

TABLE 2.1: POWER EXTRACTION FROM DIFFERENT VOLTAGE SOURCES

Transmission Line	Flux in pu	Flux in wb	Transformer output voltage	Rectifier output	Power
33kV	5	0.9	10V(p-p)	8.25V	68mW
66kV	8	1.44	20V(P-p)	8.5V	72.25mW
132kV	20	3.60	40V(p-p)	16V	256mW
220kV	30	5.40	60V(p-p)	28V	784mW

IV. RESULTS AND CONCLUSION

With the above simulation results and power extraction calculations we can conclude that the amount of energy extracted from sub transmission system i.e., 33kv, 66kv, 132kv and 220kv is sufficient enough to power up wireless sensor nodes. With the recent advances in harvesting magnetic energy which is carried out on experimental basis by other authors , this study acts as a promising means for possible magnetic energy harvesting in sub transmission system. As a further enhancement, the optimum location for placement of energy harvester and the practical realization is to be carried out.

ACKNOWLEDGMENTS

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