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Depiction and Compensation of Ferranti Effect in Transmission Line

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Abstract: A Flexible AC transmission System refers to the system consisting of various devices to enhance the stability and transfer capability of the transmission system. This method can be used during charging of the transmission line, when there is no load or low load condition at the receiving end & Due to, this low current flows through the transmission line also shunt capacitance in the transmission line will become dominant. This causes voltage amplification (Ferranti Effect) due to which receiving end voltage will become greater than the sending end voltage (effect will be high in long transmission line). To compensate the Ferranti effect, shunt inductors are connected across the transmission line. In this work Ferranti effect is reduced by designing an Inductive circuit. Proposed circuit has simulated using MATALB/Simulink& practically verified in hardware system.

Keywords: Ferranti effect, Shunt inductor, Compensation, Open circuited line

I. INTRODUCTION

There are many factors affecting temporary over voltages that may be considered in insulation.The Ferranti effect is a phenomenon where the steady voltage at the open end of an uncompensated transmission line is always higher than the voltage at the sending end. It occurs as a result of the capacitive charging current flowing through the line and resulting over voltage increases according to the increase in line length [1-3].Traditionally the most accurate transmission line models have been based on a constanttransformation matrix with frequency dependent modes [4]. This type of model may give satisfactory results for situations involving high frequency transients, but the accuracy often deteriorates in the low frequency area due to frequency dependency of the transformation matrix [5].In long transmission lines, the most important factors which affect the power frequency voltages on the line during normal operation and the increase in voltages during a fault are the length of the line and the degree of shunt compensation [6]. Both parameters have a major indirect influence on the transient phenomena as well as with normal switching operations [7-10]. In this paper Ferranti effect has been reduced considerably & proposed design has been solved by both simulink modelling & experimental setup.

II. FERRANTI EFFECT

The effect in which the voltage at the receiving end of the transmission line is more than the sending voltage is known as the Ferranti effect. Such type of effect mainly occurs because of light load or open circuit at the receiving end. It is due to the charging current of the line. When an alternating voltage is applied, the current that flows into the capacitor is called charging current. A charging current is also known as capacitive current. The charging current increases in the line when the receiving end voltage of the line is larger than the sending end.

A. Modelling of transmission Line

Ferranti effect has been explained by considering (Fig 1) a nominal pi (π) model.

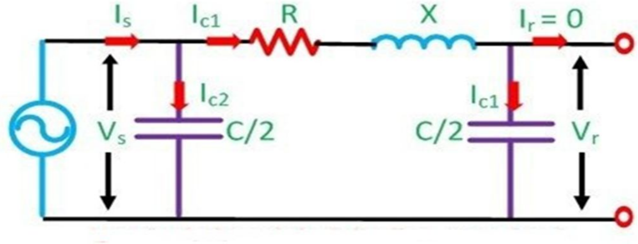

Fig 1 Block diagram of the system

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In general for a 300 Km line operating at a frequency of 50 Hz, the no load receiving end voltage has been found to be 5% higher than the sending end voltage. Now for analysis of Ferranti effect let us consider the phasor diagrams shown above. Here, Vr is considered to be the reference phasor, represented by OA.

$V_r = V_r(1 + j0)$ (1)

Capacitive current Ic= jωCVr
Sending end voltage Vs= Vr + resistive drop + reactive drop
$V_s = V_r + I_c R + jI_c X$ (2)
$V_s = V_r + I_c\,(R + jX)$ (3)
$V_s = V_r + j\omega CVr(R + j\omega L)$ (4)
Since $X = \omega L$
Now $V_s = V_r - \omega^2 CLV_r + j\omega CRV_r$
This is represented by the phasor OC in Fig 2.

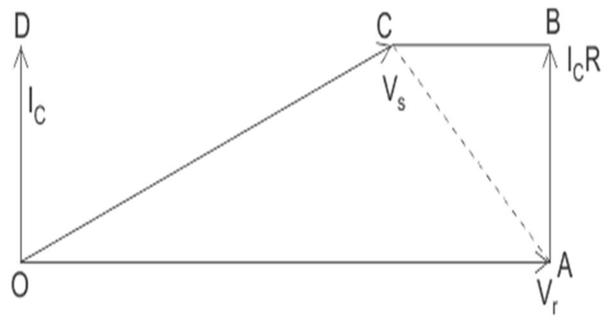

Fig 2:Phasor Diagram representing Ferranti effect

Neglecting resistance i.e. R=0
Thus capacitive reactance X_c= $(1/\omega LC_o)$
Average current flowing through capacitor I_c= $(V_r/2XC)$= $(1/2)Vr\omega lC_o$ (where l indicates length of the transmission line)
Inductive reactance of the line = ωLol
Thus raise in voltage is given by Voltage raise = $(1/2)Vr\omega^2 l^2 C_o L_o$
From the above equation it is absolutely evident, that the rise in voltage at the receiving end is directly proportional to the square of the line length, and hence in case of a long transmission line it keeps increasing with length and even goes beyond the applied sending end voltage at times, leading to the phenomena called Ferranti effect in power system.

III. PROPOSED DESIGN

The Ferranti effect is a phenomenon where the steady voltage at the open end of an uncompensated transmission line is always higher than the voltage at the sending end. It occurs as a result of the capacitive charging current flowing through the line and resulting over voltage increases according to the increase in line length. This causes voltage amplification (Ferranti Effect) due to which receiving end voltage will become greater than the sending end voltage (effect will be high in long transmission line). To compensate the Ferranti effect, shunt inductors are connected across the transmission line. In this work Ferranti effect is reduced by designing an Inductive circuit. Proposed circuit has simulated using MATALB/Simulink & practically verified in hardware system.

A. MATALB/Simulink model

Simulink model & output of the model has been given in Fig 3 & Fig 4. And output in Fig 4 clearly shows that Ferranti effect has been considerably reduced.

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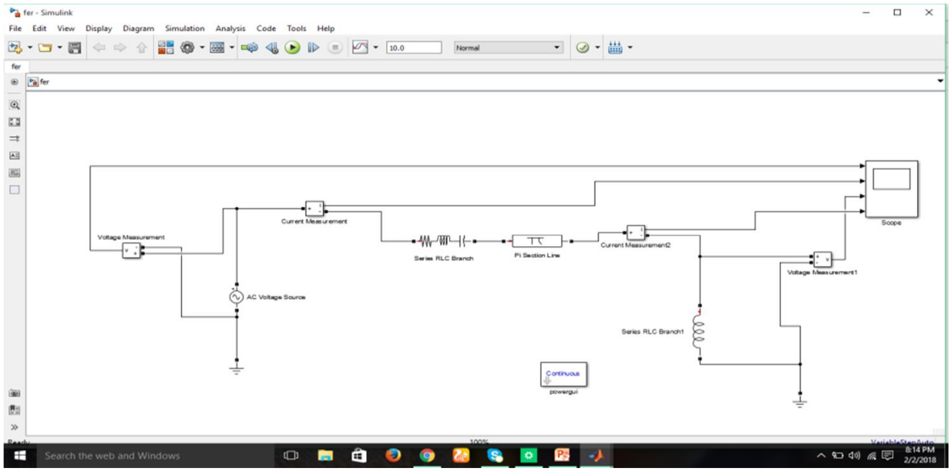

Fig 3:Simulation model

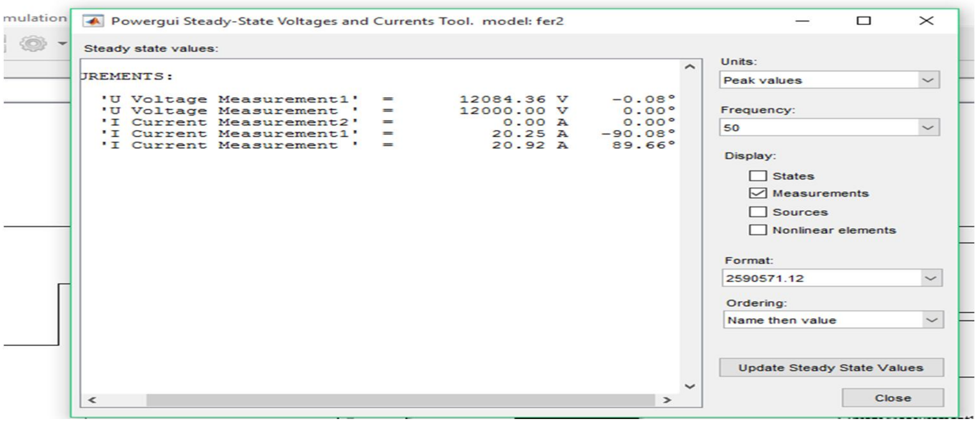

Fig 4: Simulation output after Ferranti effect compensation

B. *Hardware Design*

The system design is based on block diagram shown in Fig 5 & circuit diagram in Fig 6. Here a long transmission of certain length is considered, voltage at the sending end and receiving end is measured. Sending end voltage is compared with receiving end voltage under no-load condition. The analog data is given to Arduino Uno and it's programmed such a way that it triggers OPTO-coupler which in turn switches end to end TRIAC in such a way that inductor is shunted into the network at receiving end.

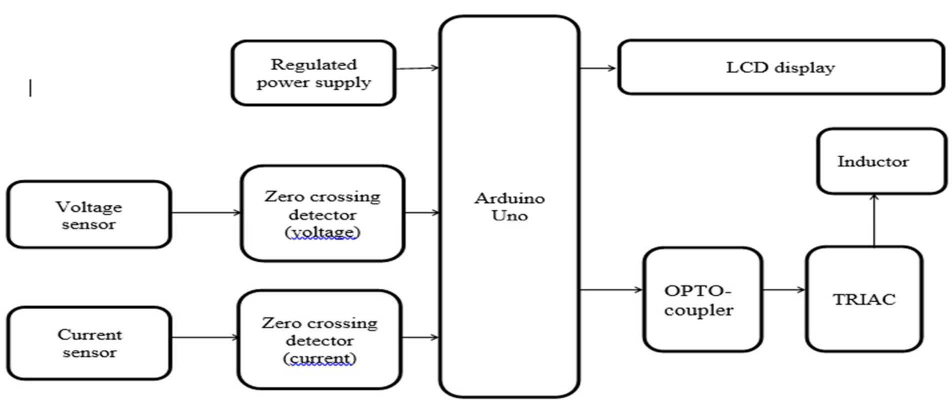

Fig 5: Block diagram of the proposed system

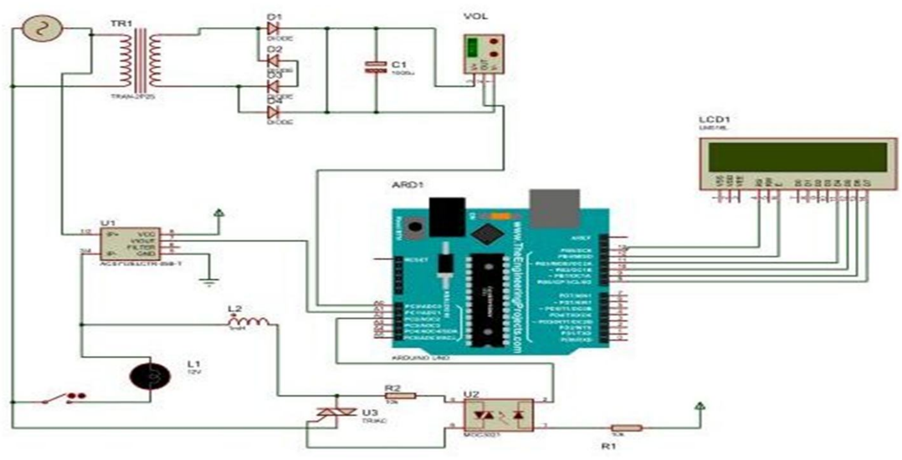

Fig 6: Circuit diagram for hardware model

IV. SIMULATION STUDY

The simulation was conducted in MATLAB/SIMULINK for various values of voltage in the sending end & output values mentioned in Table 1.

Sending end voltage	Receiving end voltage (without compensation)	Receiving end voltage (with compensation)
230V	355.28V	231.62V
3300V	5097.38V	3323.20V
6600V	10195.05V	6646.40V
12000V	18536.46V	12084.36V
220000V	339835.16V	221546.66V

Table 1 Simulation output

A. Experimental Output

220V, 50Hz supply is given to the kit & the output was observed under no-load condition shown in Table 2. Shunt inductor used to compensate the voltage raise due to Ferranti effect.

Sending end voltage	Receiving end voltage (Without compensation)	Receiving end voltage (With compensation)
213V	217V	214V
215V	219V	216V

Table 2 N of the Experimental study

V. CONCLUSION

In this paper Ferranti Effect has been successfully reduced by the proposed Inductive circuit through designed practical model. Also proposed system has been tested in Matlab/simulink. Normally in long transmission line (For example, 400 kilometres) Ferranti effect is more, where the receiving end voltage greater than the sending end voltage. As the length of line increases, effect also increases and by this work the effect has been considerably reduced by suitable design.

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