Study the relationship between the real Power and reactive Power for Inductive Load of Short transmission Line Using HP VEE

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***Abstract*—High voltage transmission lines are used to transmit electrical energy from source to substations. Study the relationship between the different elements are very important to design advance lines and provide more information about the fabrications processes, avoid some of the mistakes of manufacturing and operating, and the work system which technically leads to increase the system life and also save money.**

This paper presents a new approach to study the relationship between the real power and reactive power for inductive load of short transmission line using HP VEE programs. Interesting graphs have been shown with changing the different parameters for this relation.

***Key words*—Short transmission line, HP VEE program, voltage, seires inductuve.**

I. INTRODUCTION

In general, the power transmission line is one of the major components of an electric power system. Its major function to transport electric energy, with minimal losses, from the power sources to the load centers, usually separated by long distances. The design of transmission lines are characterized by series resistance, inductance, and shunt capacitance per unit length, these values determine the power-carrying capacity of the transmission line and the voltage drop across it at full load. The series resistance relies basically on the physical composition of the conductor at a given temperature [1]. The series inductance and shunt capacitance are produced by the presence of magnetic and electric fields around the conductors, and depend on their geometrical arrangement. The shunt conductance is due to leakage currents flowing across insulators and air [2]. As leakage current is considerably small compared to nominal current, it is usually neglected, and therefore, shunt conductance is normally not considered for the transmission line modeling [1]. Transmission lines are classified as short, medium, and long transmission lines [3]; both short- and medium-length transmission lines use approximated lumped-parameter models. However, if the line is larger than 240 km, the model must consider parameters uniformly distributed along the line.

A short-length line has length is less than 80 km (50 miles). In this case, the shunt capacitance effect is negligible and only the resistance and inductive reactance are considered. Assuming balanced conditions, the line can be represented by the equivalent circuit of a single phase with resistance, and inductive reactance in series (series impedance). The appropriate series impedance and shunt capacitance are found by solving the corresponding differential equations, where voltages and currents are described as a function of distance and time. [4-6]. In this paper we are going to drive and study the equations of short-length lines.

II. THEORETICAL MODEL

A. Equivalent Circuit

The equivalent circuit for short transmission line is presented in Fig. 1, where R is the resistances, X_L is inductive reactance, V_s is sending voltage, V_R is receiving voltage, $P(Q)$ is real power and Q is reactive power, and I_S, I_R are sending and receiving currents.

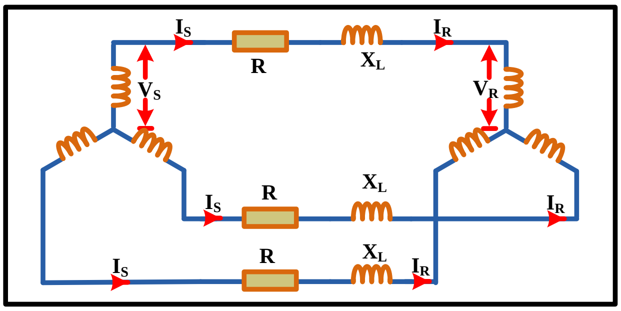

Figure.1. Equivalent circuit for three-phase and short transmission line of inductive load.

B. *Calculate the voltage equation for single phase short transmission line with inductive load*

As it was mentioned, the Equivalent circuit of Fig. 1 can reduced to the circuit of Fig. 2 by using symmetries in circuit between the three phases.

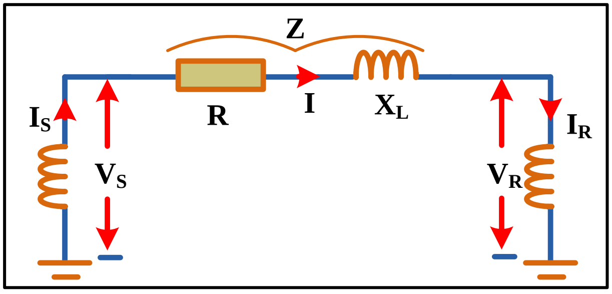

Figure. 2. Equivalent circuit for single phase short transmission line with inductive load.

Fig. 3 represented the Vector graphic between sending and receiving Voltage for single phase short transmission line with inductive load.

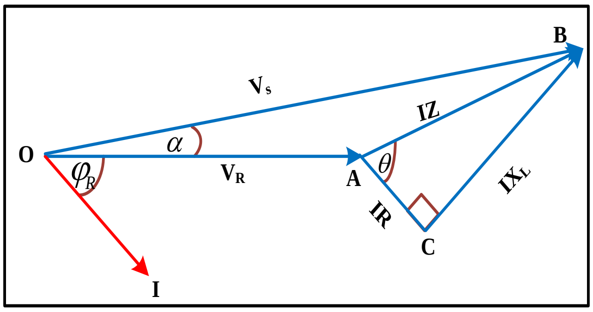

Figure. 3. Vector graphic between sending and receiving Voltage for single phase short transmission line with inductive load.

From equivalent circuit of Fig. 2 the complex equation of voltage can be written as:

$$Vs = V_R + ZI_R\angle\theta - \emptyset_R \qquad (1)$$

Where $Z = R + jX_L$ is Line impedance

By using the trigonometric relationships we get:

$$Vs = V_R + I_R(\cos\emptyset_R - j\sin\emptyset_R)(R + jX_L)$$

$$Vs = V_R + (I_R\cos\emptyset_R - jI_R\sin\emptyset_R)(R + jX_L)$$

$$Vs = V_R + (RI_R\cos\emptyset_R - jI_R R\sin\emptyset_R) + jX_L I_R\cos\emptyset_R + X_L I_R\sin\emptyset_R$$

$$Vs = V_R + (RI_R\cos\emptyset_R + I_R X_L\sin\emptyset_R) + j(I_R X_L\cos\emptyset_R - RI_R\sin\emptyset_R)$$

Straightforward calculations lead to (2)

$$Vs = (V_R + RI_R\cos\emptyset_R + I_R X_L\sin\emptyset_R) + j(I_R X_L\cos\emptyset_R - RI_R\sin\emptyset_R) \qquad (2)$$

By square the both sides of (2), and simplified we get

$$Vs^2 = (V_R + I_R R\cos\emptyset_R + I_R X_L\sin\emptyset_R)^2 + (I_R X_L\cos\emptyset_R - I_R R\sin\emptyset_R)^2 \qquad (3)$$

and

$$V_s^2 = V_R^2 + 2V_R I_R(R\cos\emptyset_R + X_L\sin\emptyset_R) + I_R{}^2(R^2 + X_L{}^2) \qquad (4)$$

From (4) we can write (5), which represented the relation between real power and reactive Power of the short line as:

$$P^2 + 2R\left(\frac{V_R^2}{Z^2}\right)P + Q^2 + 2X_L\left(\frac{V_R^2}{Z^2}\right)Q - V_S^2\left(\frac{V_R^2}{Z^2}\right) + \left(\frac{V_R^4}{Z^2}\right) = 0 \qquad (5)$$

where

$P = V_R I_R\cos\emptyset_R$

$Q = V_R I_R\sin\emptyset_R$

$S = P + jQ$

$S^2 = P^2 + Q^2$

$P^2 + Q^2 = V_R^2 I_R{}^2 = S^2$

$I_R{}^2 = (P^2 + Q^2)/V_R^2$

$Z^2 = R^2 + X^2$

The solution for (5) is give as:

$$P(Q) = -R\left(\frac{V_R^2}{Z^2}\right) + \sqrt{R^2\left(\frac{V_R^4}{Z^4}\right) - Q^2 - 2X_L\left(\frac{V_R^2}{Z^2}\right)Q + V_S^2\left(\frac{V_R^2}{Z^2}\right) - \left(\frac{V_R^4}{Z^2}\right)}$$

$$\text{if } R^2\left(\frac{V_R^4}{Z^4}\right) \geq Q^2 + 2X_L\left(\frac{V_R^2}{Z^2}\right)Q - V_S^2\left(\frac{V_R^2}{Z^2}\right) + \left(\frac{V_R^4}{Z^2}\right) \qquad (6)$$

Now the maximum value for real power can be calculated by taking the derivative for P as $\left(\frac{dP}{dQ}\right) = 0$ as:

$$P_{max} = \frac{V_R^2}{Z^2}\left[Z\frac{V_S}{V_R} - R\right] \qquad (7)$$

C. *Numerical model*

The HP VEE software was used to solve and study the (5); the HP VEE software has two parts; the internal part which uses to perform the simulation, and the outer part which uses to display the results, see Fig. 4 Simplified flowchart of HP VEE of $P(Q)$.

III. RESULTS AND DISCUSSION

As it mentioned above numerical calculations were performed to solve (5) with the following values for different parameters in table 1.

TABLE1. DIFFERENT PARAMETRS VALUES

Z/Ω	XL/Ω	R/Ω	VR/KV	Vs/KV
25	20	15	17.318	19.050

The relation between real Power and reactive Power P(Q) for constant parameters represented in fig. 5, it is clear that from the figure for small values for P, there are correspond values for Q; Q values are increased with increase P values till the maximal value $P_{max} = \left|-\frac{V_R^2 X}{Z^2}\right|$ see (7), after that Q values are increased with decrease P values.

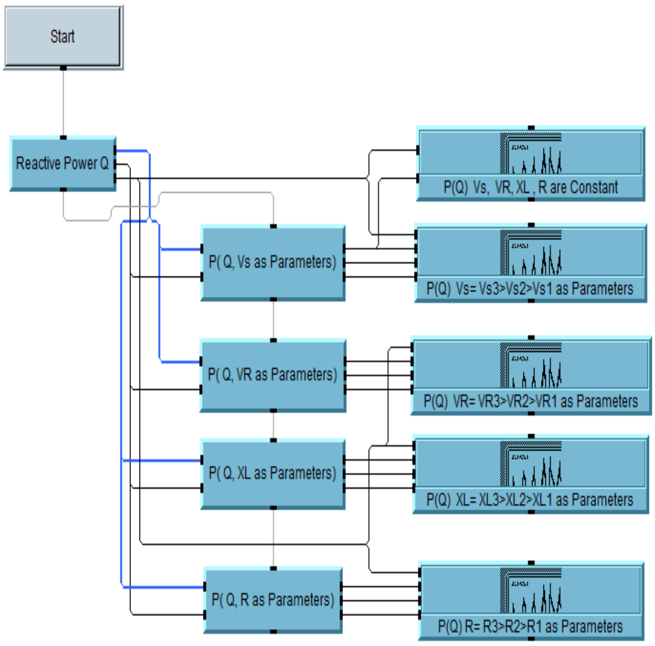

Figure 4. Simplified flowchart of HP VEE of $P(Q)$

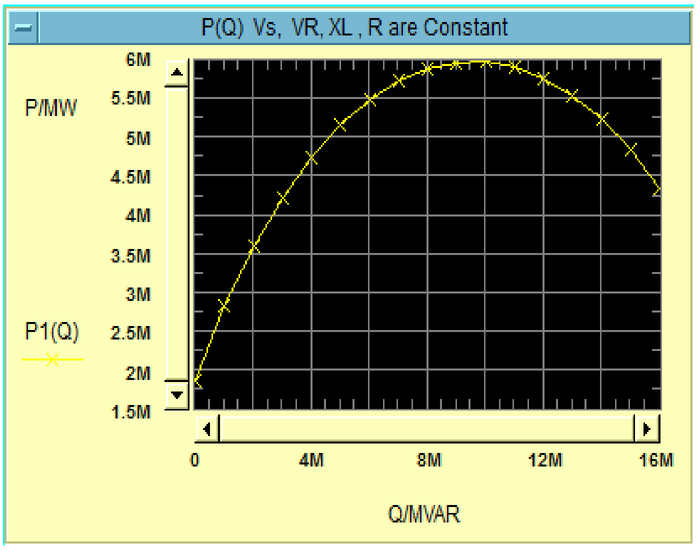

Figure. 5. The relation between real power and reactive power with constant parameters.

Fig.6 shows the relation between real power and reactive power with changing V_s is directly proportional till maximal values for real power, and this is true see (6).

Now when we change the V_R on the relation between real power and reactive power is directly proportional till the maximal values this relation becomes inversely proportional and show an interning behavior see Fig. 7, this is because V_R is presented in all parts of (6).

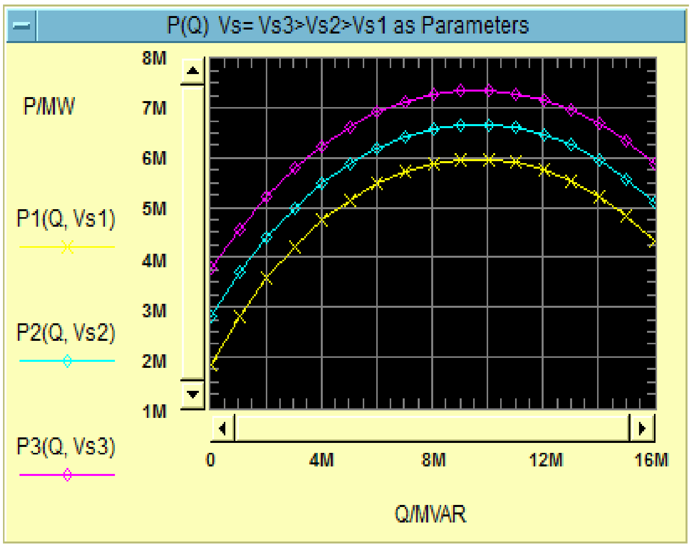

Figure. 6. The relation between real power and reactive power for change the receive voltage V_s.

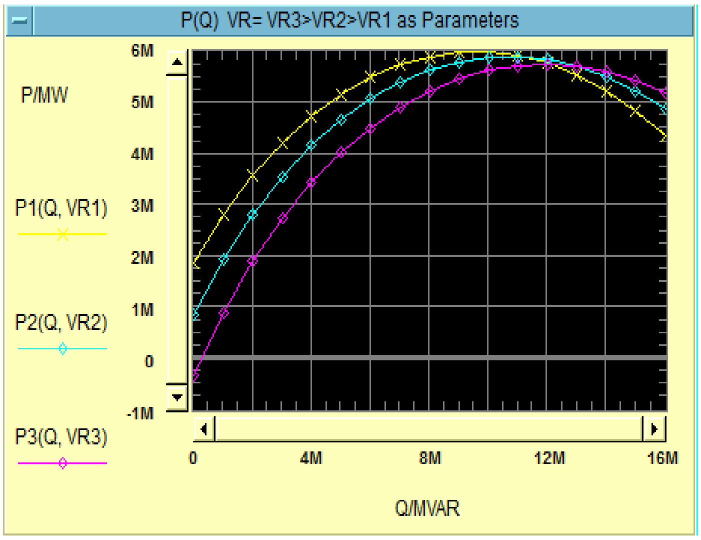

Figure. 7. The relation between real power and reactive power for change the receive voltage V_R.

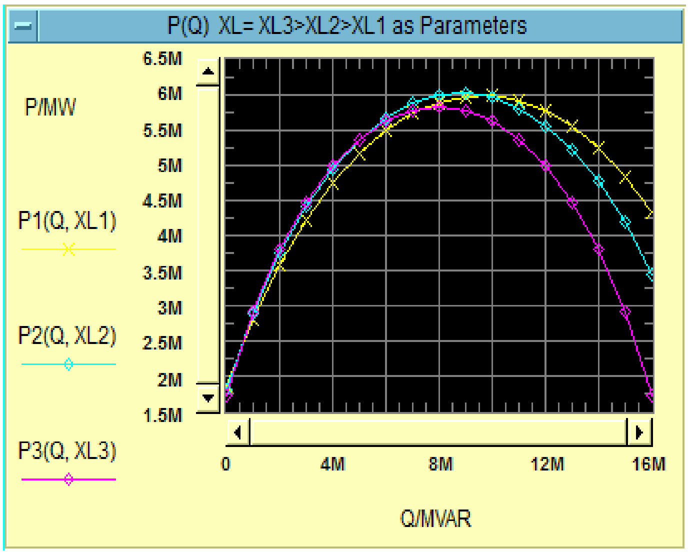

Figure. 8. The relation between real power and reactive power for changing X_L.

On the other hand, the changing on X_L shows different behavior for the relation between real power and reactive power Fig. 8, there are a small difference between the curves of different X_L values till the maximal value and this behavior is changed, which shows inversely proportional, and the differences between the curves increase with increase Q.

Finally, the influence of R on the relation between real power and reactive power is significant, and it is inversely proportional for big values of Q, this is shown in Fig. 9.

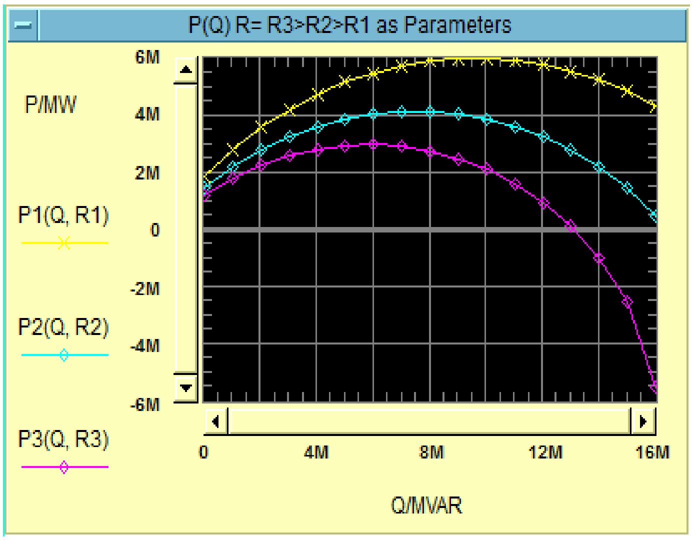

Figure. 9. The relation between real Power and reactive Power for changing the resistance.

IV. CONCLUSION

The relation between relation between real power and reactive power for three-phase and short transmission line of inductive load was successfully derived, and studied for changing different parameters, these results draw the roadmap for design advance Short transmission Line.

ACKNOWLEDGMENT

The authors acknowledge Electric and Electronic Dept, Faculty of Engineering, Aljabal Algarby University, for technical and financial support.

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