ISSN 2348 – 8034
Impact Factor- 3.155

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

UNBALANCED LOAD CONNECTED TO LONG TRANSMISSION LINE AND IT'S EFFECTS ON VOLTAGE PROFILE

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ABSTRACT

Power System loads in recent times are unbalanced and dynamically varying and are unavoidable. As a consequence load reactive power is no longer balanced and leads to voltage fluctuations, line overloading and high transmission line losses. This paper basically discusses the effects of unbalanced load on voltage profile connected to long transmission line. The system models are designed by assembling the component models and identifying the interfaces between the various components. This entire system and mechanisms are modelled in MATLAB/SIMULINK environment.

***Keywords**: Unbalanced Load, reactive power, voltage profile, power system & MATLAB.*

I. INTRODUCTION

Increasing population and industrialization created a magnificent increase in the electrical energy demand. In recent years, the electrical energy consumed by industry loads has shown greater increment than that of domestic loads. Industries are mainly equipped with increased number of unbalanced loads, which consume large amount of reactive power. Because of this reason the power factor of the load centre is degraded to a higher extent and also it decreases the power transfer capability of the transmission lines simultaneously causing under voltage problems.

Voltage control in an recent electrical power systems are most important for proper operation of electrical power equipments to prevent damages such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse. In simple terms, decreasing reactive power causing voltage to decrease while increasing it causing voltage to rise. A voltage collapse occurs when the system tries to serve more load than the voltage of the system can support. When reactive power supply lowers voltage, as voltage drops current should increase to maintain power supplied to the load, causing system to consume much more reactive power than it should and the voltage drops further to a greater extent . If the current is increased too much, transmission lines goes off line, overloading the other lines and potentially causing cascading failures which is quite destructive in nature & should be avoided. If the voltage drops too low, some of the generators connected in the system will disconnect automatically to protect themselves.

II. UNBALANCED LOAD

In electrical engineering, the three-phase electric power systems should have at least three conductors carrying alternating current and voltages that are offset in time by one-third of the period. A three-phase system could be arranged in delta (Δ) or star (Y) (may denoted as wye in some areas). The wye system allows the use of two different voltages from all the three phases, such as a 230/400 V system which provides 230 V between the neutral and any one of the other phases, and 400 V across any of the two phases. There are two types of system available in electric circuit, single phase and the other is three phase system. In single phase circuits, there will be one phase, i.e the current will flow through only one wire and there will also be one return path called neutral line to complete the circuit. So in single phase minimum amount of power will be transported. Here the generating stations and load stations will also be single phase. This is an old system used from previous time. The three phase circuit is the polyphase system where there are three phases are send together from the generator to the load. Each phase is having a phase difference of 120°. So from the total of 360°, three phases would be equally divided into 120° each. The power in three phase system is continuous as all the three phases are involved in generating the total power. The conductor required in three phase circuits is 75% that of conductor required in single phase circuit.

In three phase circuit, connections can be represented in two types:

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1. Star Connection:

In star connection, there are four wires, three wires are phase wire and fourth is called the neutral which is taken from the star point. Star connection is always preferred for long distance power transmission because it is having the neutral point which is advantageous. In this we need to come to the concept of balanced and unbalanced current in power system. When equal current flows through all the three phases, then it is called as balanced current. And when the current will not be equal in all or anyone of the phase, then it is called unbalanced current. In this case, during balanced condition there will be no current flowing through the neutral line and hence there is no use of the neutral terminal in star connection. But when there will be a unbalanced current flowing in the three phase circuit, then neutral is having a vital role in the circuit. It will take the unbalanced current to the ground and protect the transformer from being affected. Unbalanced current affects transformer and it might also cause damage to the transformer and because of this star connection is preferred for long distance transmission over delta connection.

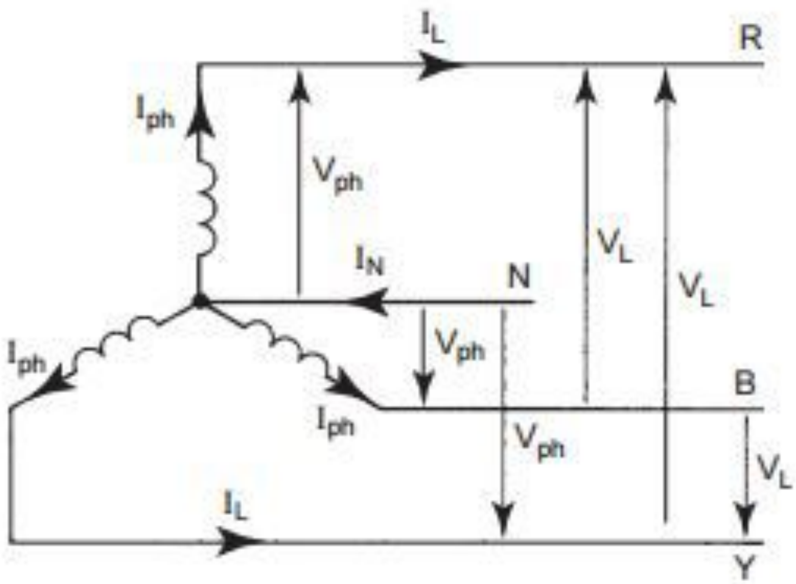

Figure1.Star Connection

2. Delta Connection:

In delta connection, there are three wires alone with no neutral terminal being taken. Normally the delta connections are preferred for short distance transmission due to the problem of unbalanced current in the circuit. In delta connection, the line voltage is always same with that of phase voltage. And the line current is √3 times to that of phase current. It is shown as expression below.

$$E_{Line} = E_{phase} \ and \ I_{Line} = \sqrt{3} I_{Phase}$$

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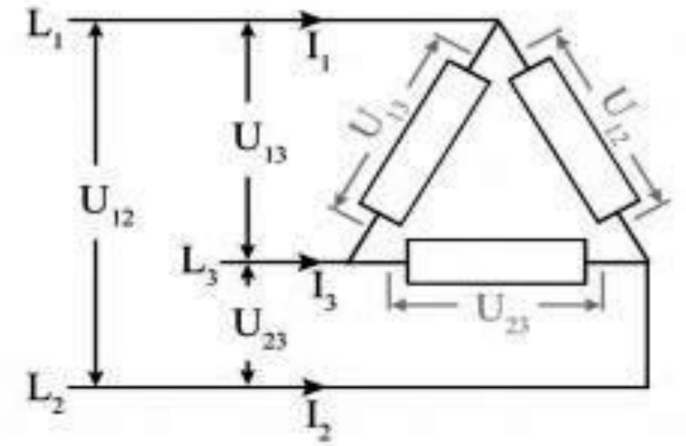

Figure2. Delta Connection

III. TRANSMISSION LINE

The transmission lines are categorized as three types. In short transmission line, the line length is up to 80 km. In medium transmission line, the line length is between 80 km to 160 km and in Long transmission line the line length is more than 160 km. Whatever may be the category of transmission line, the only aim is to transmit power from sending end to receiving end. Like other electrical systems, the transmission network will also have some power loss and voltage drop during transmitting power from sending to receiving end. Hence, performance of transmission lines can be determined by its efficiency and voltage regulation. Every transmission line has three basic electrical parameters. The conductors of the line will be having electrical resistance, inductance, and capacitance. As the transmission line is a set of conductors being run from one place to another which are supported by transmission towers, the parameters are distributed uniformly throughout the length of the line.

$$S = P + jQ$$

Where S is the Apparent Power, P is the Active Power & Q is the Reactive Power.

1. **T Representation of Transmission line:**

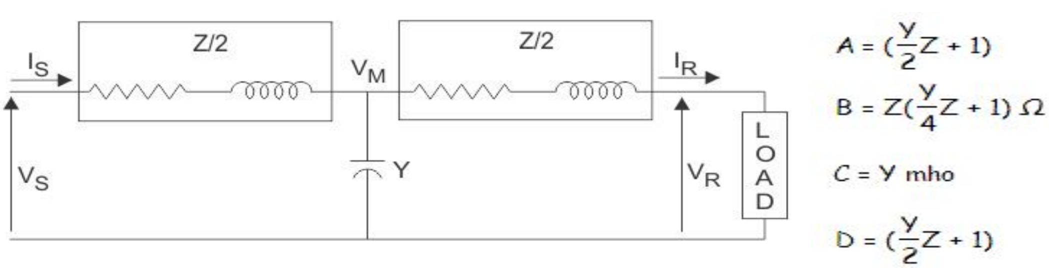

Figure3. Nominal T Representation of Medium Transmission Line & its Parameters.

2. **Pie Representation of Transmission Line:**

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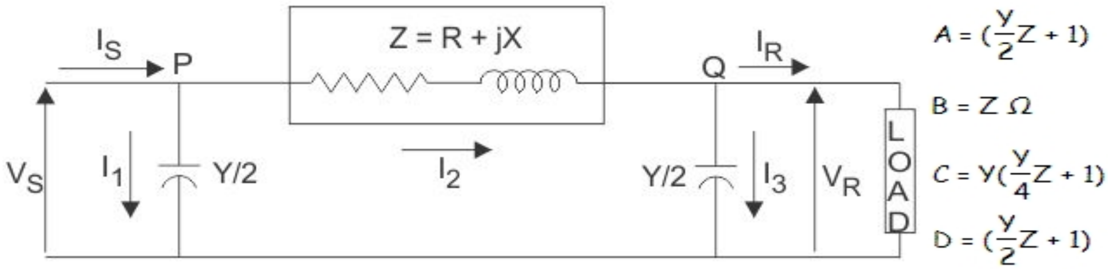

Figure4. Nominal Pie Representation of Medium Transmission Line & its Parameters.

3. Distributed Parameter Transmission Line:

A distributed parameter long transmission line of 300 KM is used. The parameters are given below.

PARAMETERS	TRANSMISSION LINE
No of Phases	3
Frequency	50
Resistance Per Unit Length	[10.01273 0.3864]
Inductance Per Unit Length	[12.1957e-3 4.1264e-3]
Capacitance Per Unit Length	[7.09e-9 7.751e-9]
Length of Line	300 KM

IV. VOLTAGE PROFILE

Under normal system conditions, both peak and off peak load conditions, the voltages need to be maintained between 95% and 105% of the nominal. Low voltage conditions could result in equipment malfunctions which may lead to generating units tripping, motors will start but may overheat & damage. High voltage conditions may lead to major damage to the insulation equipment & automatic tripping of major transmission equipment. Voltage and reactive power must be properly managed and controlled to maintain the power stability of power system. The voltage profile must be maintained flat as far as possible & should not vary more than 5% of the rated voltage. Voltage variation is caused due to the imbalance between the generation & absorption of reactive power. If the generated reactive goes high & more than consumption of reactive power than voltage level goes up and vice versa. However if the two are maintained equal than voltage profile becomes flat.

V. FERRANTI EFFECT

In electrical engineering, Ferranti effect is an increase in voltage occurring at the receiving end of a long transmission line, which is much more than the voltage at the sending end. This occurs when the line is energized, but this occurs in case of very light load or when the load is disconnected. The capacitive line charging current is responsible for voltage imbalance which produces a voltage drop across the line inductance that is in-phase with the sending end voltages while considering the line resistance as negligible at the same time . Therefore both the line inductance and capacitance are mainly responsible for this phenomenon. The relative voltage rise is proportional to the square of the transmission line length. The Ferranti effect has much more pronounced effect in underground cables, may be even in short lengths, because of their high capacitance.

VI. VOLTAGE REGULATION IN TRANSMISSION LINE

The performance of transmission line can be determined by its efficiency and voltage regulation. Voltage regulation can be defined as the measure of change in the voltage magnitude between the sending and receiving end of a component, which may be a transmission or a distribution line. Voltage regulation illustrates the ability of a system to provide nearly constant voltage over a wide range of load conditions in the system. Voltage regulation of a transmission line is the measure of change of receiving end voltage from no-load to full load condition.

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$$\%regulation = \frac{No\ load\ receiving\ end\ voltage\ -\ Full\ load\ receiving\ end\ voltage}{Full\ load\ receiving\ end\ voltage} 100\%$$

$$\text{Percent } VR = \frac{|V_{nl}| - |V_{fl}|}{|V_{fl}|} \times 100$$

where V_{nl} is voltage at no load condition and V_{fl} is voltage at full load condition. A smaller value of Voltage Regulation is usually beneficial for the power system under consideration.

VII. RESULTS AND DISCUSSIONS

A MATLAB Simulink model is developed to study the 3 phase Unbalanced Load connected to 300 KM Long Distributed Parameter Transmission Line.

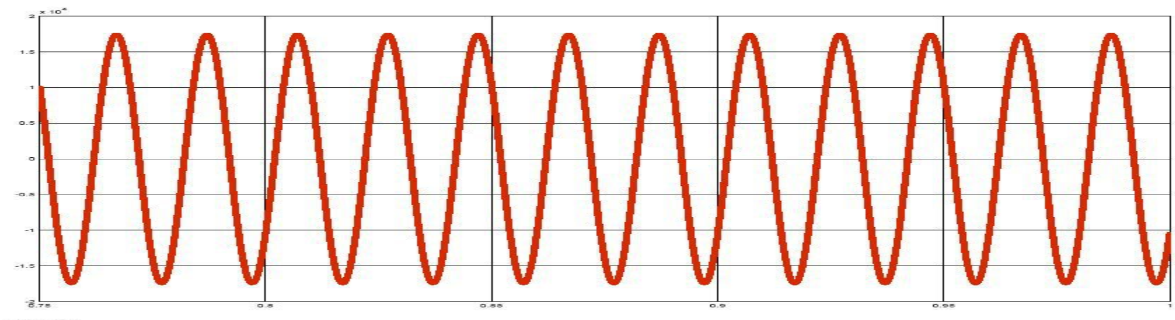

Figure5. Voltage Waveform at Generator Side of 13.8KV.

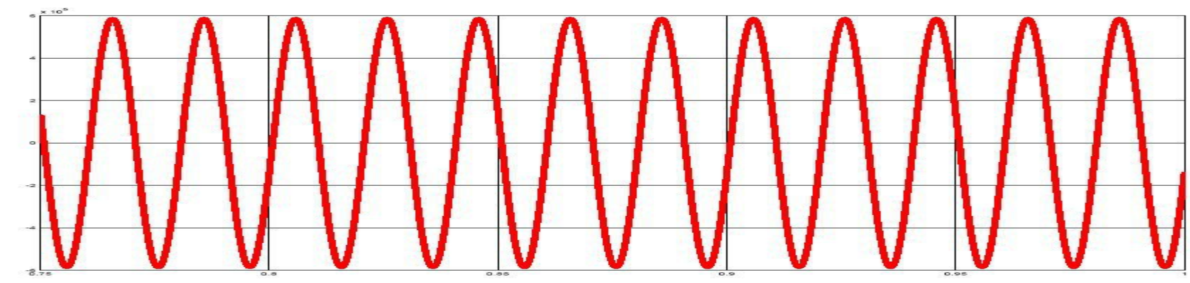

Figure6. Voltage Waveform at Sending End after being Stepped Up to 415 KV.

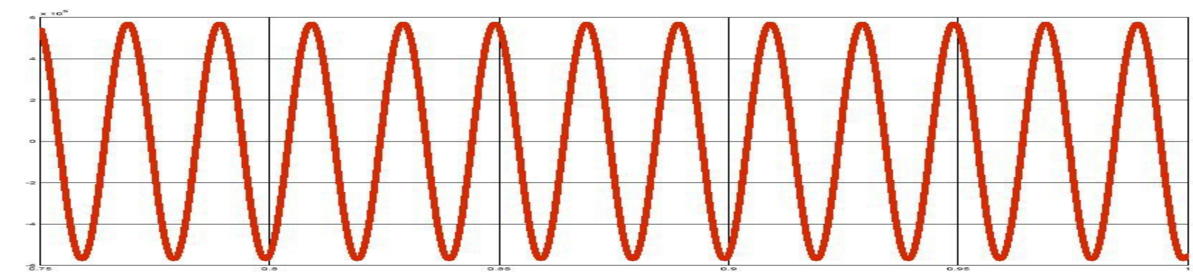

Figure7. Voltage Waveform at Receiving End to 405 KV.

Table showing Simulation Results.

PARAMETERS	SENDING END	RECEIVING END
Voltage	415 KV	405 KV
Active Power	72 MW	195 KW

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Reactive Power	56.37 MVAR	195 KVAR
Current	141.9 A	39.4 A

VIII. CONCLUSIONS

Voltage drop of approximately more than 10 KV was found at the receiving end of transmission line. This drop in voltage is because of dynamically varying loads or unbalanced loads. These loads consume large amount of reactive power. The power calculation method can be used to make steady state controllers to control the reactive power individually in each phases of any three phase system. A Dynamic Reactive Power must be designed to minimize reactive power & improve voltage profile. DRPC can be used to improve power quality in the city area, where low voltage problems are being addressed. Furthermore this can also be effectively used to enhance the power transfer capability of the transmission lines. Therefore the distribution lines can be extended effectively to a greater extent to electrify the rural areas of the country.

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