Designing & Performance of Medium Transmission Line using Mathematical Method

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***Abstract:-* The example described in this section illustrates about the Medium transmission line system performance with changing in distance with the respect power factors. In this paper we discussed about the design and the performance of the medium transmission line in form of Nominal Pie method and reduce the costing by using a simple mathematical problem. However, in this study we have to construct well designed systems to get better performance of transmission line by using mathematical method.**

Key words:* *Performance, Transmission-line, Designs, Voltage-Regulation.

I. INTRODUCTION

In modern power systems are highly complicated and are hope for to carry out the growing requires of power wherever needed. To control and to stabilize the power of the AC transmission system some workable performance is done by the medium transmission line. Therefore the design and the performance of medium transmission lines can be controlled by resistance, capacitance and inductance of the line. Such as in the electrical system, the transmission network as well as its have some power losses and voltage dropping in the time of transferring power from the sending end to the receiving end of the system. Thus the performance of transmission line can be decided by its distance, line to line voltage, sending end currents, sending end power factor, sending end power, voltage regulation and transmission efficiency of the system. In this paper we discussed about the medium transmission line using nominal pi methods for design and the performance.

II. THEORETICAL DETAILS

A *transmission line* is used to transfer the electrical power from generating station to the distribution stations. It transmits the wave form of current and voltage from one side to another side. A transmission line come across it's with an actual length more than 80 km but less than 250 KM is regard as a medium transmission line.

Medium transmission line is three types:

a) Nominal π (Pi) Method.
b) Nominal **T** Method.
c) End Condenser Method.

Here we only discuss about the Nominal π (Pi) Method. [1] In this method, capacitance of each conductor is divided into two halves; one half being lumped at the sending end and the other half at the receiving end as shown in [2] below figure. It is obvious that capacitance at the sending end has no effect on the line drop. However, it's charging current must be added to line current in order to obtain the total sending end current.

I_R = load current per phase
R= resistance per phase
X_L = inductive reactance per phase
C = capacitance per phase
$cos\, \emptyset_R$ = receiving end power factor (lagging)
V_S = sending end voltage per phase

From the phasor diagram for the circuit is shown in above Figure. Taking the receiving end voltage as the reference phasor, we have,

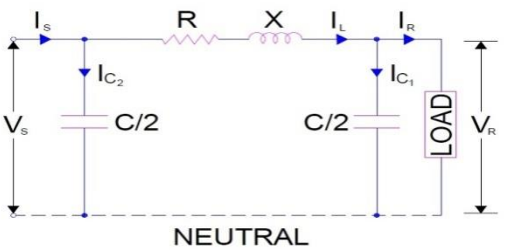
$$\bar{V}_R = V_R + j\,0$$

Load current, $\vec{I}_R = I_R\,(cos\,\emptyset_R\ - j\,sin\,\emptyset_R\,)$

Charging Current at load end is, $\vec{I}_{C1} = j\,\omega\,(C/2)\,\vec{V}_R = j\,\pi\,f\,C\,\vec{V}_R$

Line current, $\vec{I}_L = \vec{I}_R + \vec{I}_{C1}$

Sending end voltage, $\vec{V}_S = \vec{V}_R + \vec{I}_L\,\vec{Z} = \vec{V}_R + \vec{I}_L(R + j\,X_L)$



Charging current at the sending end is, $\vec{I}_{C2} = j\omega(C/2)\vec{V}_S = j\,\pi\,f\,C\,\vec{V}_S$

Therefore, Sending end current, $\vec{I}_S = \vec{I}_L + \vec{I}_{C2}$

% Voltage Regulation = $\frac{V_S - V_R}{V_R}$ *100

Transmission Efficiency = $\frac{Receiving\ \ end\ Power}{Sending\ end\ Power}$ *100

Losses = *(Sending end Power – Receiving end Power)*

The word *Performance* contain the calculation of sending end current, sending end voltage, sending end power factor, efficiency of transmission, voltage regulation, power loss in the lines and limits of power flows during steady state and short-term condition. [3] An incompetent design can lead to power cuts and for that reason hamper everyday life of people as well as the industries which is depending on electricity. For this we have to construct well design system for better performance, better stability reduce the costing of the transmission line to analysis the systems and avoid the power losses & the power cuts. A better perception of designs response of those systems under different loading is necessary to avoid such cuts and the losses.

The motive of a voltage regulator is to retain the voltage in a circuit almost near to a desired value. Voltage regulators are one of the most important electronic parts, which maintain the system stability as an unregulated power supply usually produces unbalanced current that would destruct the equipments in the system or creating a fault in the system. A voltage regulator may be used if the power comes up with constantly produces a voltage which is bigger than what the equipments in the system needs. This type of voltage regulator firstly includes of a resistor with a specific set of performance features. [5] A reactive voltage regulator is to minimize the arriving voltage to the required production level and dumping ground the extra energy as heat. Reactive regulator usually needs a heat sink to dissolve this additional heat. Circuits that need the voltage to enlarge will need an active voltage regulator. Such voltage regulators as usual use some kind of negative feedback loop to manage the voltage. This means that a voltage outer the required range because the voltage regulator to initiate the voltage back to its defined range. In this way voltage regulator is to be stop modifying in the circuit voltage. [7] Reducing voltage drop means stepping up voltage at receiving end. They have to add series capacitors to their transmission line with individual phase at some distances of the line. The capacitive reactance X_c will separate part of the inductive reactance X_L and in consequence the entire impedance Z will reduce.

SL No.	Distance in KM at delivers voltage.	Power Factor	Receiving end voltage per phase in kV	Sending end voltage in kV	Line to Line voltage in kV	Sending end current in amps	Sending end Power Factor	Sending end Power MW	Power Losses in MW	Voltage Regulation %	Transmission Efficiency %
1	100 (110kV)	0.7	63.508	79.67	137.98	357.74	0.63	53.86	3.86	25.46	92.83
2		0.8	63.508	76.32	132.2	314.56	0.73	52.58	2.58	20.18	95.09
3		0.9	63.508	72.91	126.89	281.01	0.85	52.24	2.24	14.81	95.71
4	150 (110kV)	0.7	63.508	87.78	152.05	347.91	0.61	55.89	5.89	38.23	89.46
5		0.8	63.508	82.88	143.55	306.4	0.72	54.85	4.85	30.51	91.15
6		0.9	63.508	77.88	134.9	274.96	0.8301	53.32	3.32	22.64	93.77
7	200 (110kV)	0.7	63.508	95.86	168.15	336.98	0.5931	57.17	7.17	50.96	87.45
8		0.8	63.508	89.45	154.94	297.27	0.7001	55.84	5.84	40.86	89.54
9		0.9	63.508	84.68	146.68	268.13	0.8201	55.86	5.86	33.35	89.5
10	100 (220kV)	0.7	127.017	134.14	232.338	160.71	0.7871	50.9	0.9	5.61	98.23
11		0.8	127.017	132.424	229.366	143.31	0.8905	50.7	0.7	4.26	98.62
12		0.9	127.017	130.727	226.425	132.77	0.9713	50.57	0.57	2.92	98.87
13	150 (220kV)	0.7	127.017	137.072	237.417	167.54	0.7441	51.27	1.27	7.91	97.52
14		0.8	127.017	134.513	232.983	148.49	0.8509	50.98	0.98	5.9	98.06
15		0.9	127.017	131.981	228.599	135.85	0.9451	50.84	0.84	3.91	98.35
16	200 (220kV)	0.7	127.017	139.59	241.78	138.49	0.8893	51.57	1.57	9.99	96.96
17		0.8	127.017	136.14	235.81	127.14	0.9713	51.23	1.23	7.18	97.6
18		0.9	127.017	132.85	230.095	128.17	0.9798	49.66	-0.34	4.59	100.68

Efficiency denotes a top level of performance that uses the minimum amount of inputs to accomplish the highest amount of output. It keeps down the waste of materials such as physical materials & energy. [4] Voltage regulation is the proportion of voltage drop from no load to the full load to the no load voltage. The ideal voltage regulation should be 0%. It should be as low as feasible for proper functioning of the electrical devices. And time while achieving the required production output.

[6] Electric service is focus to supply service to the consumers at a particular voltage level. Genuine service voltage regulation within endurance of band such as ±5% or ±10% may be thinking about acceptable. In order to keep voltage within toleration under switching load conditions and different types of devices are conventionally engaged. So voltage regulation and the transmission efficiency are main factor of power system. In real or ideal power system voltage regulation and the transmission efficiency should be 0 and 100%. But it is not practically possible in any transmission line under full loaded or unloaded state because transmission lines itself is reactive type and their maximum loads are too in reactive type. Hence, it is impossible to keep this limit in practical system. As the toleration limit of voltage regulation is ±5% or ±10% Therefore voltage regulation also permissible limit is ±5% or ±10%. As in modern power system network is fully alliance. So, it is very hard to keep such range. Voltage regulation is not only determined upon only sending end voltage and receiving end voltage but also it too depending upon line length, power factor, active and reactive power flow and transmission length too.

For that reasons modern power system design criteria is allowable limit of voltage regulation up to 20% and efficiency more than 90% and it considering from 95%.

III. Problem Statement

In this paper we will finding out how to changing design parameters by changing line length and power factor at particular load. As a design Engineer it is first and foremost duty to find out design parameters before delivering loads of any line length because, every line length is not suitable to delivery to a particular load. So this paper is high lightening how to choose optimum line length and power factor to deliver the load, then only any power station will achieve optimum profit otherwise it will be run as unprofitable organization.

IV. Illustration

To prove our statement we considered a power system problem. We have analysis our condition in different cases. Changing our problem for 100 KM, 150 KM & 200KM length and power factor 0.7, 0.8, 0.9 as well as change in delivers voltage 110kV & 220kV.

[1]A 3-phase, 50Hz, 100KM, 150 KM & 200 KM line has a resistance, inductive reactance and capacitive shunt admittance of 0·1 Ω, 0·5 Ω and 3×10^{-6} S per km per phase. If the line delivered 50 MW at 110 kV, 220kV and 0.7, 0·8 & 0.9 power factor lagging. Determine the sending end voltage and current, sending end power factor, sending end power, voltage regulations, losses and transmission efficiency. Assume a nominal π circuit for the line.

By solving in mathematical problems in nominal **π** methods for medium transmission, we got below results by testing in different conditions.

Table 01:

Above data table is obtain by mathematical methods and data table is obtain by MS Excel®.

V. COMMENT

By analysis above mentioned data table we concluded below idea. For distribution of higher load we have to choose to proper distribution criteria that is proper length, proper transformer design, proper loss design, proper voltage modifiers design, reactive power and compensation. Because if we not design properly and ignore all then distribution company will be effected as huge monitory loss .If power loss occurred due to unbalancing condition they not only effected efficiency but also voltage regulation will be effected .As a distribution engineer it is his duty to analysis or set different power distribution criteria by analyzing line parameters to set the installation charge for distribution load.

We have see that when we distributed 50MW power in short transmission line with low voltage it is not economical but when we distributed same power in 100KM, 150KM, 200KM length it will be much more economical by comparing voltage regulation ,line loss, efficiency ,sending and receiving end voltage,. So we can conclude that distribution of higher load is economical in medium and long transmission lines. Here we have analysis medium (long 200KM) transmission lines.

VI. DECISION

Design of a distribution line firstly identified optimum transmission line length and voltage by analysis of performance of transmission line by suitable for design criteria .Mathematical modeling is very important to give any idea or taking any decision, Here we have tested our analysis by changing different criterion. Our analysis method is

Analysis of Voltage regulation and efficiency of a transmission line,

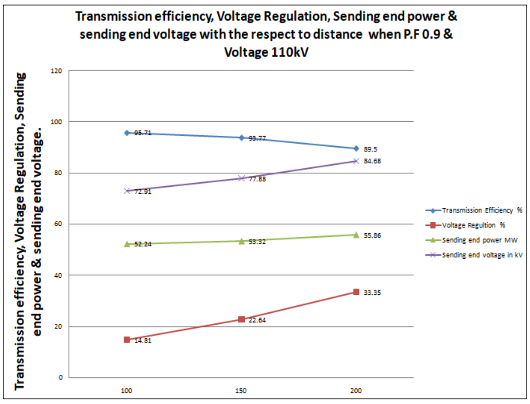
Table 02:

SL No.	Distance in KM	Power Factor	Power Losses in MW	Voltage Regulation %	Transmission Efficiency %
1	100	0.7	3.86	25.46	92.83
2	(110KV)	0.8	2.58	20.18	95.09
3		0.9	2.24	14.81	95.71
4	150	0.7	5.89	38.23	89.46
5	(110KV)	0.8	4.85	30.51	91.15
6		0.9	3.32	22.64	93.77
7	200	0.7	7.17	50.96	87.45
8	(110KV)	0.8	5.84	40.86	89.54
9		0.9	5.86	33.35	89.5
10	100	0.7	0.9	5.61	98.23
11	(220KV)	0.8	0.7	4.26	98.62
12		0.9	0.57	2.92	98.87
13	150	0.7	1.27	7.91	97.52
14	(220KV	0.8	0.98	5.9	98.06
15		0.9	0.84	3.91	98.35
16	200	0.7	1.57	9.99	96.96
17	(220KV)	0.8	1.23	7.18	97.6
18		0.9	-0.34	4.59	100.68

VII. ANALYSIS

Case 1: In 100 KM length, we have seen that for distribution of load 50MW, Voltage regulation and efficiency is better in higher power factor at higher voltage. When load distributed 110kV then the voltage regulation of Transmission line 25.46, 20.18, 14.81 & the transmission efficiency are 92.83, 95.09 and 95.71 and when distribution voltage220 KV then it comes on 5.61, 4.21, 2.92 at power factor 0.7, 0.8 & 0.9 respectively and efficiencies are 98.23, 98.62 and 98.87.

Case 2: 150 KM length, we have seen that for distribution of load 50MW, Voltage regulation and efficiency is better in higher power factor at higher voltage. When load distributed 110kV then the voltage regulation of Transmission line 38.23, 30.51, 22.64 & the transmission efficiency are 89.46, 91.15, and 93.77 and when distribution voltage 220 KV then the voltage regulation comes on 7.91, 5.9, 3.91 at power factor 0.7, 0.8 & 0.9 respectively and efficiencies are 97.52, 98.06, and 98.35.

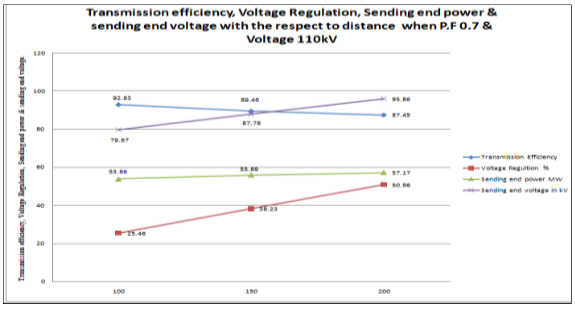


Case 3: 220 KV length, we have seen that for distribution of load 50MW, Voltage regulation and efficiency is better in higher power factor at higher voltage. When load distributed 110kV then the voltage regulation of Transmission line 50.96, 40.86, 33.35 & the transmission efficiency are 87.45, 89.54, and 89.5 and when distribution voltage 220 KV then the voltage regulation comes in 9.99, 7.18, 4.59 at power factor 0.7, 0.8 & 0.9 respectively and efficiencies are 96.96, 97.6, and 100.68. Here the efficiency 100.68 which is not feasible designs.

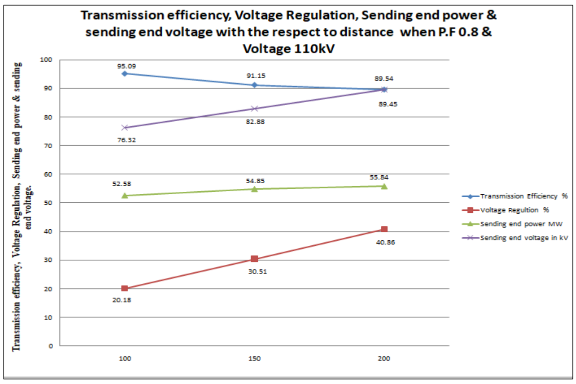
So we can concluded that higher load (50MW) distribution design is better to transmit higher voltage then transmission loss will less and regulation and efficiency is improved and overall voltage profile improved.

VIII. Results

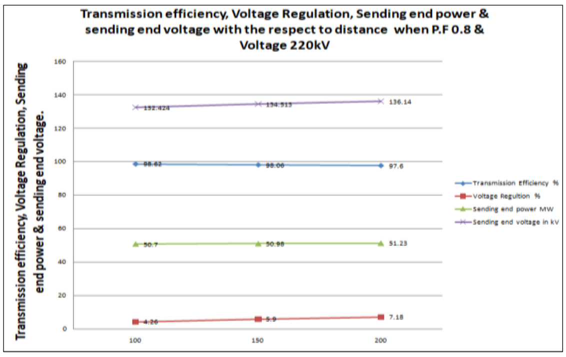
Here, Blue line is described about the Transmission efficiency, Red line is described about the Voltage regulation, Green line is described about the Sending end Power and the Purple line described about the sending end voltage.



Again, above graph is described about the performance, when the voltage is 110kV at the power factor 0.7, 0.8. It's clearly give us the concept that we can't design at this voltage and its performance because of its voltage profile which is get higher than its margin line.

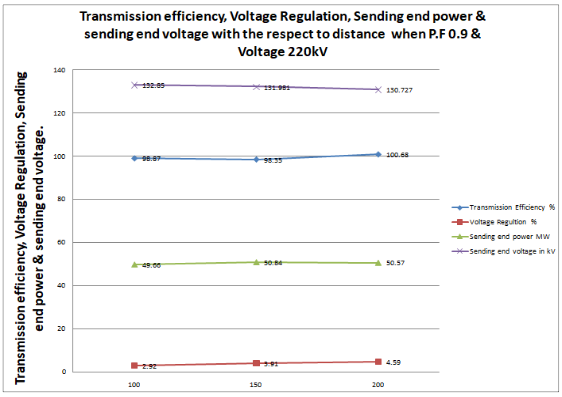


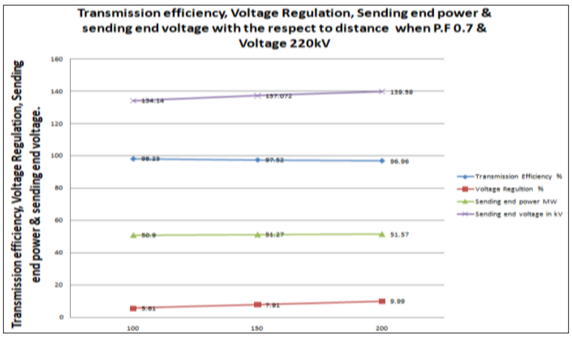
Again, above graph is described about the performance, when the voltage is 110kV at the power factor 0.9. It's clearly give us the concept that we can't design at this voltage and its performance because of its voltage profile which is get higher than its margin line. But at the graph in the distance 100km we can consider for the designing and the performance of the line.



Above graph is obtained from MS. Excel ®.

Again, above three graphs are described about the performance, when the voltage is 220kV at the power factor 0.7, 0.8 & 0.9. It's clearly give us the concept that we can design at this voltage and its performance because of its voltage profile which is best than its margin line.





IX. CONCLUSION

It is clear that after analysis data that transmission line design is very important. Any voltage, any length is not suitable for power distribution. In any design criteria will be optimal when it will be analyzed via mathematical model. The performance of a power system under normal balanced steady-state conditions is of primary importance in power system engineering. The transmission line is the main energy corridor in a power system. The performance of a power system mainly on the design of transmission lines in the power system. The important considerations in the operation of the transmission lines are voltage drop and power losses occurring in the line and efficiency of transmission. So this research having large impact in research area of transmission line.

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