PERFORMANCE OF SHORT TRANSMISSION LINE USING MATHEMATICAL METHOD

Mrs. Suparna Pal[1], Arindam Das[2]
[1]Assistant professor, Department of Electrical Engineering, JIS College of Engineering, Kalyani, Nadia, West Bengal, 741235
[2]EDPS student, Department of Electrical Engineering, JIS College of Engineering, Kalyani, Nadia, West Bengal, 741235

ABSTRACT
The example described in this section illustrates about the short transmission system performance with changing in distance with the respect of voltage and the power factors. In this paper we discussed about the performance of the transmission line and reduce the costing 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 and matlab programming.
Key words: Performance, Transmission-line, Costing, Voltage-Regulation.

Introduction
In modern power systems are highly complicated and are hope for to carry out the growing needs of power wherever essential. To control and to stabilize the power of the AC transmission system some flexible performance is done by the short transmission line. Therefore the performance of short transmission lines can be controlled by resistance 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 sending end power, voltage regulation and transmission efficiency of the system.

Theoretical Details
A *transmission line* is used to *transmit 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 its length less than 80 km is regard as a short transmission line. In the short transmission line capacitance is overlook for the reason of small leakage of current and other parameters like inductance and resistance are combined in the transmission line. 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. [1]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 a 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. 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.
Reducing voltage drop means stepping up voltage at receiving end. That 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.

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.
Electric service is focus to supply service to the consumers at a particular voltage level. Genuine service voltage regulation within a endurance of band such as ±5% or ±10% may be think 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% to 10%. Therefore voltage regulation also permissible limit is +-5 to 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%.

Mathematical details

As presented initially the impacts of line capacitance are overlooked for a short transmission line. [2] Therefore, while studying the performance of such line, only resistance and inductance of the line are taken into account. The equivalents circuit of a single phase short transmission line shown in below [3] fig. 1. Here, the total line resistance and inductance are shown as concentrated or lumped instead of being distributed. [2]The circuit is a simple A.C series circuit.

Let us assume,
I = load current
R = loop resistance *i.e.*, resistance of both conductors
X_L = loop resistance
V_R = receiving end voltage
Cos $\varnothing_R$ = receiving end power factor (lagging)
V_S = sending end voltage
Cos $\varnothing_S$ = sending end power factor

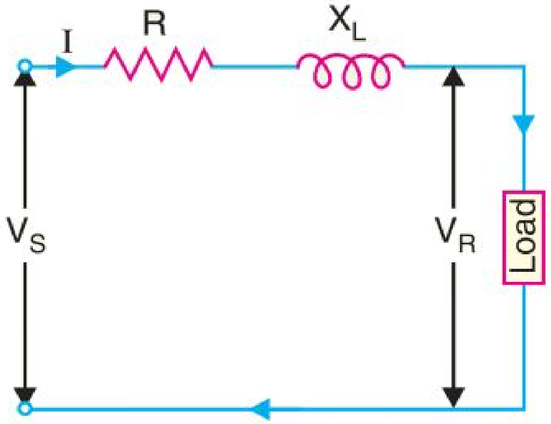


fig. 1.

Voltage regulation = $\frac{V_S - V_R}{V_R} * 100$
Sending end power factor. Cos $\varnothing_S$ = $\frac{V_R \, Cos\varnothing_{R+IR}}{V_S}$
Power delivered = $V_R \, I_R$ Cos $\varnothing_R$
Line losses = I^2R

Power sent out = $V_R I_R \cos \phi_R + I^2R$

Percentage of Transmission efficiency = $\frac{\text{Power delivered}}{\text{Power sent out}} * 100$

$$= \frac{V_R I_R \cos\phi_R}{I^2R + V_R I_R \cos\phi_R} * 100$$

Modelling Analysis:

A 220, 132, 66-kV, three phase transmission line is 40, 60, 80 km long. The resistance per phase is 0.15Ω per km and the inductance per phase is 1.3263mH per km. the shunt capacitance is negligible. Use the short line model to find the voltage and power at the sending end and the voltage regulation and efficiency when line is supplying a three-phase load of 381 MVA at 0.7, 0.8, 0.9 power factor lagging at 220kV.

Data Table

Table no. 01

SL No.	*Distance (KM)*	*Sending End Voltage (kV)*	*Power factor*	*No-Load receiving End Voltage (kV)*	*No-Load sending current (amps)*	*Sending end Power (MW)*	*Sending end power Factor*	*Voltage Regulation*	*Transmission efficiency*
1	40	220	0.7	127	999.86	284.7	0.6623	12.82	93.67
2	40	132	0.7	76.21	1666.4	316.69	0.6104	36.17	84.21
3	40	66	0.7	38.1	3332.5	466.65	0.4912	149.34	57.15
4	40	220	0.8	127	999.86	322.8	0.7570	13.6	94.4
5	40	132	0.8	76.21	1666.4	354.79	0.69	34.16	85.91
6	40	66	0.8	38.1	3332.5	504.75	0.5413	144.73	60.38
7	40	220	0.9	127	999.86	360.9	0.8580	10.4	95.07
8	40	132	0.9	76.21	1666.4	392.89	0.7900	30.53	87.27
9	40	66	0.9	38.1	3332.5	542.85	0.6	136.98	63.16

SL No.	*Distance (KM)*	*Sending End Voltage (kV)*	*Power factor*	*No-Load receiving End Voltage (kV)*	*No-Load sending current (amps)*	*Sending end Power (MW)*	*Sending end power Factor*	*Voltage Regulation*	*Transmission efficiency*
1	40	220	0.7	127	999.86	284.7	0.6623	12.82	93.67
4	40	220	0.8	127	999.86	322.8	0.7570	13.6	94.4
7	40	220	0.9	127	999.86	360.9	0.8580	10.4	95.07

From this table it is seen that SL no 1,4,7 is optimize design analysis of short transmission line because to deliver of same load in same distance if P.F is 0.9 then Voltage regulation is 10.4 and the Transmission efficiency is 95.07 which is satisfied all voltage profile criteria, so we can concluded that if we want to supply this load 381 MW in 220kV voltage in 40 KM length then power factor should be 0.9 otherwise in design criteria it will become costly because if we supplied it in PF 0.7 and 0.8 then efficiency and regulation little bit dropped, so maintained proper voltage profile and stability we need to design extra voltage regulator hardware in that circuit for that reasons cost criteria will be changed.

3	40	66	0.7	38.1	3332.5	466.65	0.4912	149.34	57.15
6	40	66	0.8	38.1	3332.5	504.75	0.5413	144.73	60.38
9	40	66	0.9	38.1	3332.5	542.85	0.6	136.98	63.16

Same load cannot be transmitted in 40 KM length via 66,132 KV in any power factor because voltage regulation and efficiency criteria (Equality constraint) are violated if we designed in this voltage then we will faced huge monetary loss because to improved Voltage profile (inequality to equality) huge hardware investment required and sometimes it is not feasible design also because Voltage regulation is 149.34, 144.73, 136.98.and efficiency is less than 60%.That means huge losses are occurred in this system.(Active & Reactive) .So we cannot modelled our load in that voltage ranges.

Table no. 02

SL No.	***Distance (KM)***	***Sending End Voltage (kV)***	***Power factor***	***No-Load receiving End Voltage (kV)***	***No-Load sending current (amps)***	***Sending end Power (MW)***	***Sending end power Factor***	***Voltage Regulation***	***Transmission efficiency***
1	60	220	0.7	127	999.86	293.69	0.6460	19.33	90.8
2	60	132	0.7	76.21	1666.4	341068	0.5796	54.72	78.05
3	60	66	0.7	38.1	3332.5	566.62	0.4562	225.98	47.06
4	60	220	0.8	127	999.86	334.87	0.7278	8.09	91.02
5	60	132	0.8	76.21	1666.4	379.78	0.6561	51.93	80.25
6	60	66	0.8	38.1	3332.5	604.72	0.4949	220.69	50.4
7	60	220	0.9	127	999.86	369.89	0.8378	15.89	92.7
8	60	132	0.9	76.21	1666.4	417.88	0.7448	47.25	82.05
9	60	66	0.9	38.1	3332.5	642.82	0.5410	211.83	53.34

SL No.	***Distance (KM)***	***Sending End Voltage (kV)***	***Power factor***	***No-Load receiving End Voltage (kV)***	***No-Load sending current (amps)***	***Sending end Power (MW)***	***Sending end power Factor***	***Voltage Regulation***	***Transmission efficiency***
1	60	220	0.7	127	999.86	293.69	0.6460	19.33	90.8
4	60	220	0.8	127	999.86	334.87	0.7278	8.09	91.02
7	60	220	0.9	127	999.86	369.89	0.8378	15.89	92.7

From this table it is seen that SL no 1,4,7 is optimize design analysis of short transmission line because to deliver of same load in same distance if P.F is 0.8 then Voltage regulation is 8.09 and the Transmission efficiency is 91.02 which is satisfied all voltage profile criteria, so we can concluded that if we want to supply this load 381 MW in 220kV voltage in 60 KM length then power factor should be 0.8 otherwise in design criteria it will become costly because if we supplied it in PF 0.7 and 0.9 then efficiency and regulation little bit dropped or getting high so maintained proper voltage profile and stability we need to design extra voltage regulator hardware in that circuit for that reasons cost criteria will be changed and it became higher.

3	60	66	0.7	38.1	3332.5	566.62	0.4562	225.98	47.06
6	60	66	0.8	38.1	3332.5	604.72	0.4949	220.69	50.4
9	60	66	0.9	38.1	3332.5	642.82	0.5410	211.83	53.34

Same load cannot be transmitted in 60 KM length via 66,132 KV in any power factor because voltage regulation and efficiency criteria (Equality constraint) are violated if we designed in this voltage then we will faced huge monetary loss because to improved Voltage profile (inequality to equality) huge hardware investment required and sometimes it is not feasible design also because Voltage regulation is 225.98, 220.69 & 211.83 and efficiency is less than 60%.That means huge losses are occurred in this system.(Active & Reactive) .So we cannot modelled our load in that voltage ranges.

Table no. 03

SL No.	***Distance (KM)***	***Sending End Voltage (kV)***	***Power factor***	***No-Load receiving End Voltage (kV)***	***No-Load sending current (amps)***	***Sending end Power (MW)***	***Sending end power Factor***	***Voltage Regulation***	***Transmission efficiency***
1	80	220	0.7	127	999.86	302.69	0.6311	25.88	88.1
2	80	132	0.7	76.21	1666.4	366.67	0.5549	73.45	72.73
3	80	66	0.7	38.1	3332.5	666.59	0.4342	302.93	40
4	80	220	0.8	127	999.86	340.79	0.7199	24.24	89.43
5	80	132	0.8	76.21	1666.4	404.77	0.6240	70.13	75.3

6	80	66	0.8	38.1	3332.5	704.7	0.4656	297.24	43.2
7	80	220	0.9	127	999.86	378.89	0.8184	21.51	90.5
8	80	132	0.9	76.21	1666.4	442.88	0.7064	64.53	77.42
9	80	66	0.9	38.1	3332.5	742.73	0.5028	287.72	46.16

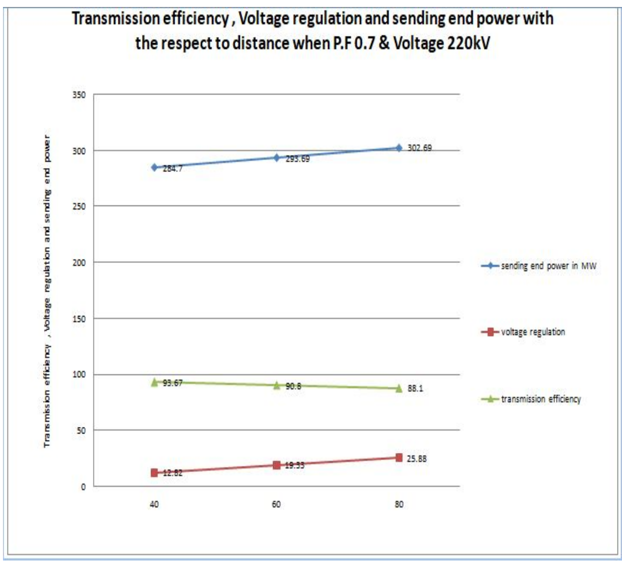
SL No.	***Distance (KM)***	***Sending End Voltage (kV)***	***Power factor***	***No-Load receiving End Voltage (kV)***	***No-Load sending current (amps)***	***Sending end Power (MW)***	***Sending end power Factor***	***Voltage Regulation***	***Transmission efficiency***
1	80	220	0.7	127	999.86	302.69	0.6311	25.88	88.1
4	80	220	0.8	127	999.86	340.79	0.7199	24.24	89.43
7	80	220	0.9	127	999.86	378.89	0.8184	21.51	90.5

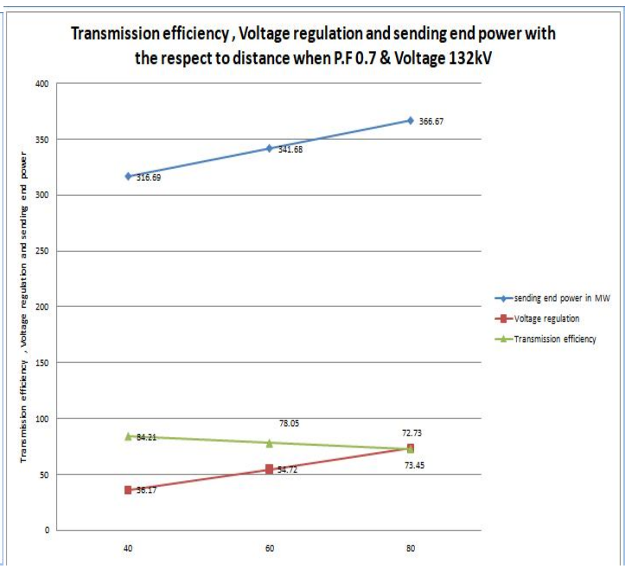
From this table it is seen that SL no 1,4,7 is not optimize design analysis of short transmission line it is optimize design for the long and the medium transmission line because to deliver of same load in same distance if power factor is 0.9 then Voltage regulation is 21.51 and the Transmission efficiency is 90.5 which is not satisfied all voltage profile criteria, so we can concluded that if we want to supply this load 381 MW in 220 kV voltage in 80 KM length then the design criteria it will become costly because if we supplied it in power factor 0.7 and 0.8 then efficiency and regulation little bit dropped or getting high so maintained proper voltage profile and stability we need to design extra voltage regulator hardware in that circuit for that reasons cost criteria will be changed and it became higher in medium and long transmission line, it is not suitable for the short transmission line.

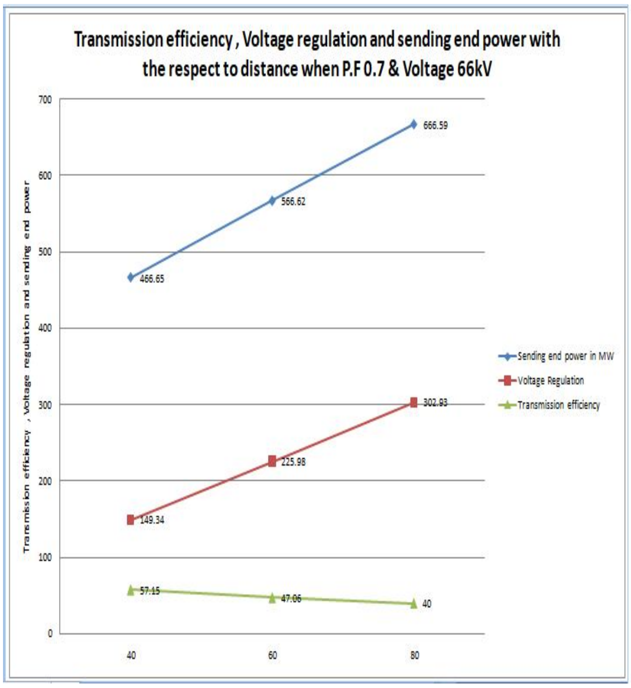
3	80	66	0.7	38.1	3332.5	666.59	0.4342	302.93	40
6	80	66	0.8	38.1	3332.5	704.7	0.4656	297.24	43.2
9	80	66	0.9	38.1	3332.5	742.73	0.5028	287.72	46.16

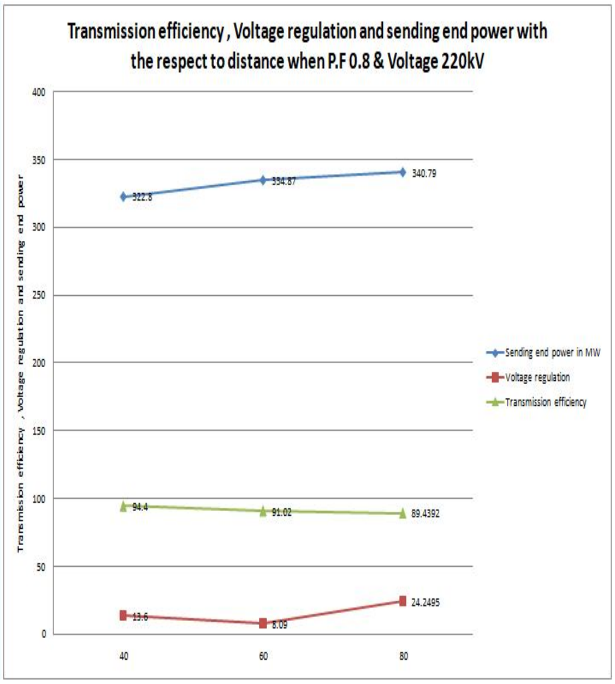
Same load cannot be transmitted in 80 KM length via 66,132 KV in any power factor because voltage regulation and efficiency criteria (Equality constraint) are violated if we designed in this voltage then we will faced huge monetary loss because of its length and it become long or medium transmission, to improved Voltage profile (inequality to equality) huge hardware investment required and sometimes it is not feasible design also because Voltage regulation is 302.93, 297.24 & 287.72 and efficiency is less than 60%.That means huge losses are occurred in this system.(Active & Reactive) .So we cannot modelled our load in that voltage ranges as well as in this length 80 KM.

Results:






Transmission efficiency , Voltage regulation and sending end power with the respect to distance when P.F 0.7 & Voltage 66kV
Transmission efficiency , Voltage regulation and sending end power
Sending end power in MW
Voltage Regulation
Transmission efficiency
466.65
566.62
666.59
149.34
225.98
302.93
57.15
47.06
40


Transmission efficiency , Voltage regulation and sending end power with the respect to distance when P.F 0.8 & Voltage 220kV
Transmission efficiency , Voltage regulation and sending end power
Sending end power in MW
Voltage regulation
Transmission efficiency
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94.4
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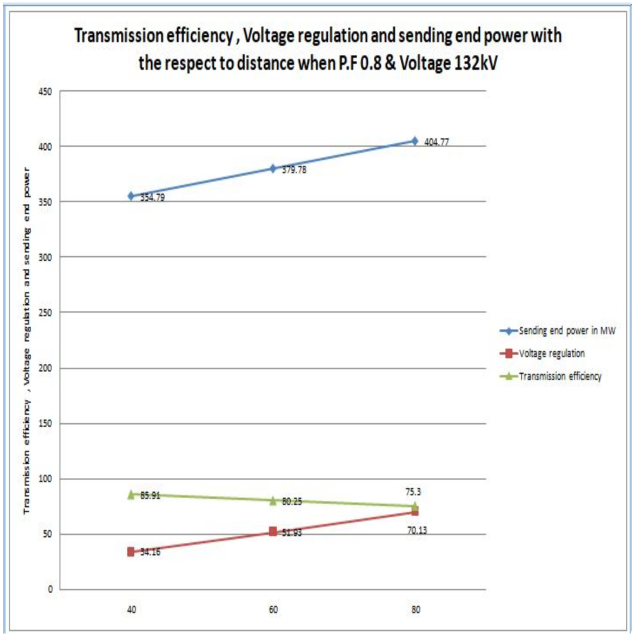
13.6
8.09
24.2495


Transmission efficiency , Voltage regulation and sending end power with the respect to distance when P.F 0.8 & Voltage 132kV
Transmission efficiency , Voltage regulation and sending end power
Sending end power in MW
Voltage regulation
Transmission efficiency
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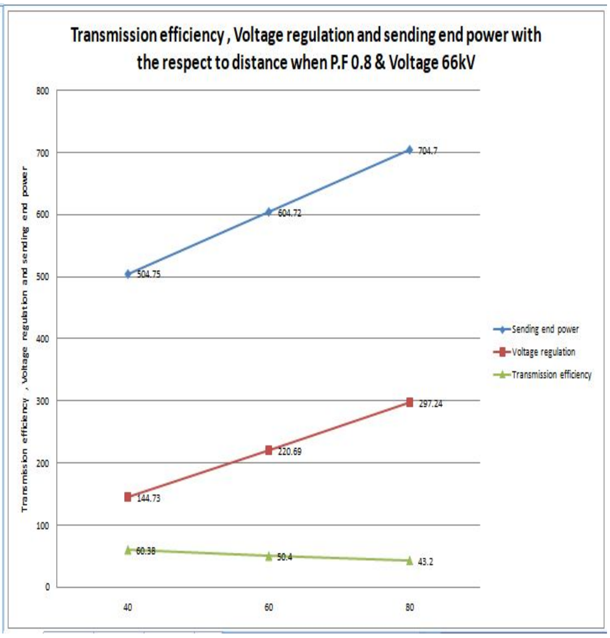
34.16
51.93
70.13


Transmission efficiency , Voltage regulation and sending end power with the respect to distance when P.F 0.8 & Voltage 66kV
Transmission efficiency , Voltage regulation and sending end power
Sending end power
Voltage regulation
Transmission efficiency
504.75
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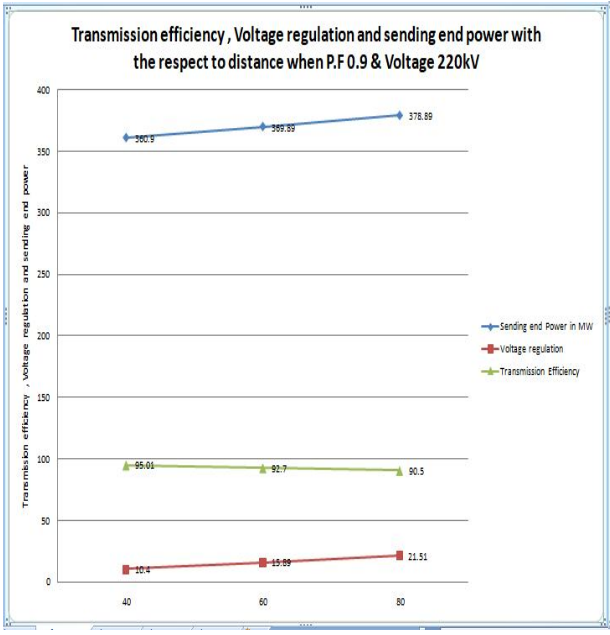
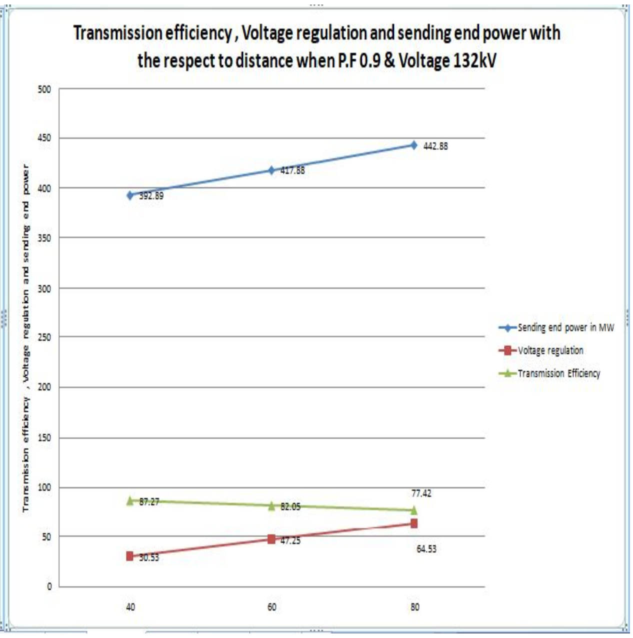
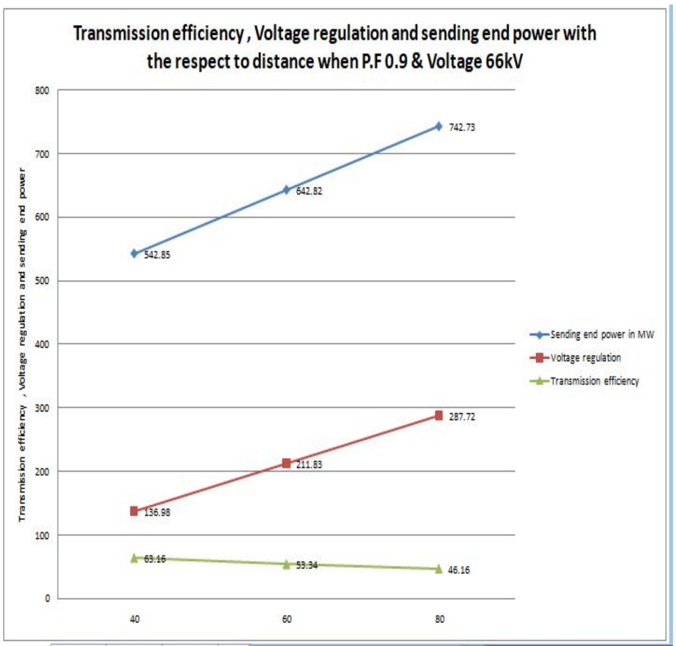
60.38
50.4
43.2







Above trends is obtain from Microsoft excel® clearly show the improvement and the losses of Short transmission line

Conclusion

The voltage regulator is generally used to compensate for the reactive power to maintain the system stability by making a balanced voltage profile in the load. As we know that the consumers demand is never constant so increasing or decreasing demand will affect system voltage, frequency and load angle. If we supplied it in fault condition huge loss will occur (power loss / monetary loss) in the power Transmission Company. So, restructured companies never run to optimize economic scheduling. So, it is our duty to maintain the system as a profitable organization. As the power system runs as industry, no industry can survive as it is run as an unprofitable organization. For that reason to distribute the load to the consumer it is required the design of proper load modelling to decide the connection charge and tariff. Without load modelling we cannot find the actual cost of power loss and voltage profile improvement equipment (voltage regulator, reactive power compensator, sag devices) and maintenance cost. This paper is highlighting how to model a transmission line before distributing the load or the choice of design parameter on the load for a short transmission line. Similar modelling analysis can be applicable for medium and long transmission lines. So this paper has a wide application area for load designing.

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Author

Mrs Suparna Pal, Asst Prof, JISCE, Kalyani, Nadia. Passed M.Tech from University of Calcutta in 2002, having 17 years teaching experience. Her research interested areas are power Systems, Control System, Renewable Energy.

Arindam Das, EDPS student, JISCE, Kalyani, Nadia. Pursuing M.Tech from JISCE. His interested area in power systems.