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Analysis of Corona Losses on the Nigerian 28-Bus, 330 kV Transmission Grid

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Abstract: ***Transmission losses that include corona losses are very common at high voltage power transmission level. The research work investigated the effects of the lengths and the radii of the transmission line sections on the corona loss .Distance values between generating stations and each of the 28 bus stations of the Nigerian 330 kV transmission grid were estimated. As a result, losses were estimated based on the radii of transmission line sections and the distance of load centres to the generating stations. It was discovered that, consideration should be given to these parameters in the design and construction of transmission and distribution lines in order to minimize losses that could result from corona discharge. In addition, losses due to corona discharges are fixed and are independent of the amount of energy being transmitted.***

Keywords: corona; losses;transmission; grid

1. Introduction

Nigeria transmits electricity through the Nation grid, which could be in 330kV or 132kv. Transmission grid is a network that consists of conductors carried on steel towers in between transformer stations, which conveys generated power from power stations to major load centres.It also interconnects all power stations to form a solid network that is accessible to all load centres [1]. The Nigeria power sector has its peculiar problems affecting electricity generation and transmission/distribution [2].

a) Transmission Power Losses

Some portion of the units of energy generated is lost in the transmission and distribution. The total transmission losses are approximately 17% while distribution losses are approximately 50% [3]. The two types of transmission and distribution losses are technical losses and non-technical losses [4]. Technical losses result mainly from power dissipation in transmission and distribution lines, transformers and measurement systems [2]. The main reason for losses in transmission lines is the result of the heat produced in the conductor's resistance because of the flow of current. The rise in the conductor's temperature further increases the resistance of the conductor which in turn increases the loss [5]. Depending on whether the losses vary with the amount of current or not, technical losses can be of fixed type or variable type [3].

While fixed technical losses do not vary according to the current, variable losses are proportional to the square of the current. Some of the examples of fixed losses are corona losses, dielectric losses e.t.c

b) Factors Influencing Technical Losses in transmission Lines

It has been shown that some of the factors leading to high technical losses in transmission lines are [6]:

1) lengthy distribution line in practically 11KV and 415V lines that results in high line resistance and therefore high I^2R losses in the line
2) Inadequate size of conductors of transmission line
3) Installation of distribution transformers away from load centers. The result of this is that the farthest consumers obtain an extremely low voltage because of increased voltage drop along the line.
4) Low power factor of primary and secondary distribution systems

c) Corona Losses

Corona discharge effect in the transmission lines is a phenomenon in which ionization of the surrounding air of power conductors takes place at voltages greater than critical break down voltage [7][8]. The electrostatic stress on the air medium gives rise to ionization when the potential difference between the phases increases further. The ionized air acts as a virtual conductor and increases the effective diameter of the power conductor. Further increase in the potential difference in the transmission lines makes the insulating medium present between the power conductors to start conducting .This results in the breakdown of the insulating medium and flash over is observed [7].

d) Calculation of Corona Loss

According to Peek's formulas, the power loss due to corona under fair weather conditions can be expressed as [8].

$$P_f = \frac{243}{\delta}(f+25)\sqrt{\frac{r}{d}}(V_{ph}-E_{dcv})^2 L(10^{-5}) \quad kW/km/phase \qquad (1)$$

Where,

δ is the air density correction factor=0.9104,

f is operating frequency of the line, which is 50Hz for Nigeria power system ,

V_{ph} is phase voltage of the line= $\frac{330}{\sqrt{3}} kV$,

E_{dcv} is the disruptive critical voltage=55.98kV,

L is the length of the conductor,

r is the radius of the conductor,

d is the conductor spacing=3m

e) Nigerian Electricity Network and Energy Capacity

Sadoh (2005) as reported by [9] explained that the Nigerian Electricity Network comprises 11,000 km transmission lines (330 and 132 kV), 24000 km of sub-transmission line (33 kV), 19000 km of distribution line (11 kV) and 22,500 substations. The existing 330kV transmission system uses double and single circuit twin Bison ACSR (Aluminium Conductors, Steel Reinforced) overhead lines. Bison is a 350-mm^2 conductor, with a continuous current rating of about 680 A per conductor [11].

Fig.1 shows the single line diagram of the existing 28 bus 330 kV Nigerian transmission network [9].

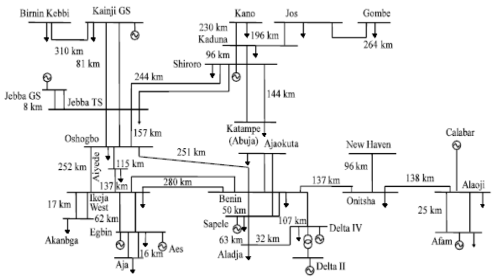

Figure 1: Single line diagram of Nigerian 28-bus 330 KV transmission grid

Table1 shows the Nigerian principal power stations with the available capacities and the 28-bus stations of the 330kV transmission lines [1] [9].

Table 1: Nigerian principal power stations and the 28 bus stations for 330kV transmission lines

Generating Station capacities		330kV 28-Bus Stations	
Power stations	Available Capacity (MW)	Existing Bus Stations	
Kainji	400	Osogbo	Afam GS
Shiroro	400	Benin	Jebba
Jebba	400	Ikeja West	Jebba GS
Egbin/AES	1,200	Ayede	Kainji GS
Omotosho	250	Jos	B Kebbi
Papalanto	200	Onitsha	Shiroro
Geregu	360	Akangba	Kaduna
Okpai	450	Gombe	
Ihovbor	360	Abuja	
Sapele	360	Egbin-PS	
Warri	200	Delta-PS	
Egbema	270	AES	
Calabar	561	Okpai	
Delta	500	Calabar	
Omoku 1	200	Aladja	
Omoku II	120	Kano	
Egbema	270	SAP PS	
Ibom	155	Aja	
Afam	350	Ajaokuta	
Shell	420	N Haven	
Alaoji	305	Alaoji	

As of December 2014, the total installed capacity of the power plants was 7,445 MW while the available capacity was 4,949 MW.

2. Material and Method

Lengths of the sections of the transmission lines between generating stations and each of the buses were extracted from the single line diagram of the 330kV transmission grid. The existing 330kV overhead line conductors are of 350mm^2 in size (or of radius of about 10.6mm) [9].Peek's formula shown in equation (1) was used to simulate and estimate the amount of corona loss in each of the sections of the transmission lines using the Microsoft Excel package. The values obtained are as shown in table 2.

Table 2: Corona Losses in Transmission Lines between Generating and Bus stations

Generating-Bus Stations	Length (Km)	Conductor's Corona loss P_f At a spacing d=3m (KW/phase).		
		Radius 1.06cm	Radius 0.53cm	Radius 0.265cm
Kainji–Kebbi	310	1723.3	1218.5	861.6
Kainji-Jebba	81	3446.6	2437.1	1723.3
Shiroro-Jebba	157	5385.3	3808.0	2692.6
Jebba-Jebba	8	6893.1	4874.2	3446.6
Shiroro-Osogbo	244	10770.5	7615.9	5385.3
Shiroro-Kano	230	13355.4	9443.7	6677.7
Shiroro-Kaduna	96	13570.9	9596.0	6785.4
Shiroro-Kano	326	17448.2	12337.8	8724.1
Shiroro-Abuja	144	20679.4	14622.5	10339.7
Shiroro-Benin	495	23048.9	16298.0	11524.5
Sapele-Benin	50	29726.6	21019.9	14863.3
Sapele-Aladja	63	31019.1	21933.8	15509.5
Delta –Benin	107	33819.4	23913.9	16909.7
Delta –Aladja	32	49544.4	35033.2	24772.2
Egbin-Ikeja West	62	52560.1	37165.6	26280.1
Egbin-Aja	16	66777.2	47218.6	33388.6
Afam-Alaoji	25	70223.8	49655.7	35111.9
Calabar-Onitsha	138	106628.1	75397.5	53314.1

3. Results

Using Microsoft Excel package fig.2, fig.3 and fig.4 show the results obtained for conductor radial values of 1.06cm, 0.53cm and 0.265cm.

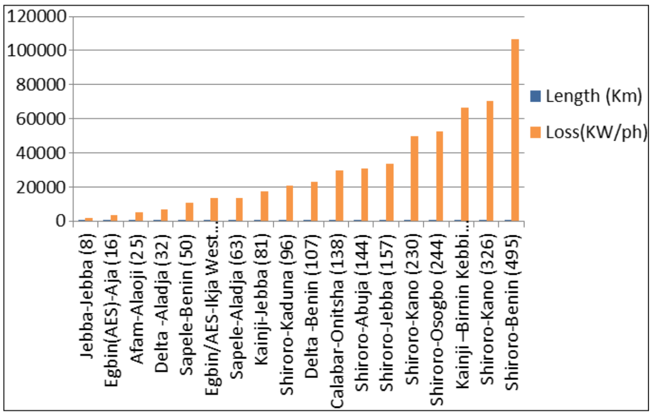

Figure 2: Corona loss increase with line length (at conductor, radius=1.06cm)

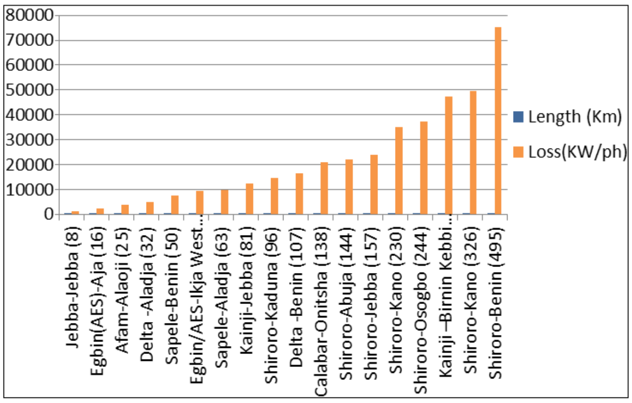

Figure 3: Corona loss increase with line length (at conductor, radius=0.53cm)

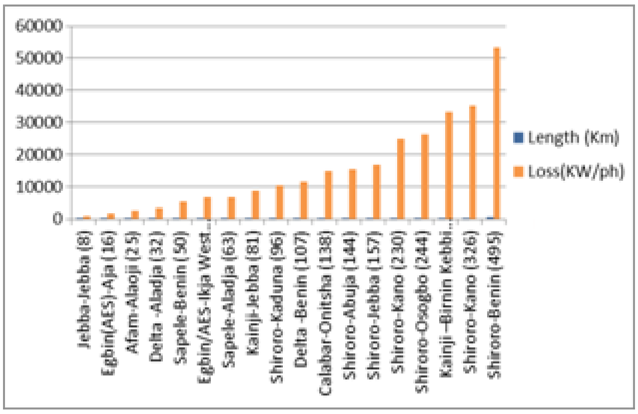

Figure 4: Corona loss increase with line length (at conductor, radius=0.265cm)

4. Observations and Comments

From fig.2, fig.3 and fig.4, it can be observed that the corona loss increases with the length of the transmission line from each generating station to the load centres. On the other hand, there is drop in the losses as the radius of the transmission line conductors reduces. In addition, the percentage of losses introduced by each transmission line section reduces with decrease in radius. Also, the amount of the losses is independent of the amount of the amount of energy being transmitted or distributed

5. Conclusion

In conclusion, it has been shown that the farther away a generation station is to load centre, the higher the value of corona loss. It is therefore of utmost importance to cite generation station close to load centres in order to reduce corona loss.

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