Department of EE+EEE
I MID TERM TEST (Feb. 2018)

SEM…VIII **SUB: EHV AC/DC TRANSMISSION** **Code: 8EE1A/8EX1A**
TIME: 1Hr **Max. Marks=20**

Q.1 What is the need of EHV transmission & what are the problems associated with? 10

Ans. NEED OF EHV AC TRANSMISSION:-

- Increase in size of generating unit
- Pithead steam plant & remote hydro plant
- Right of way problem
- Line costs
- Loading limit

Industrial-minded countries of the world require a vast amount of energy of which electrical energy forms a major fraction. There are other types of energy such as oil for transportation and industry, natural gas for domestic and industrial consumption, which form a considerable proportion of the total energy consumption. Thus, electrical energy does not represent the only form in which energy is consumed but an important part nevertheless. It is only 150 years since the invention of the dynamo by Faraday and 120 years since the installation of the first central station by Edison using dc. But the world has already consumed major portion of its natural resources in this short period and is looking for sources of energy other than hydro and thermal to cater for the rapid rate of consumption which is outpacing the discovery of new resources. This will not slow down with time and therefore there exists a need to reduce the rate of annual increase in energy consumption by any intelligent society if resources have to be preserved for posterity. After the end of the Second World War, countries all over the world have become independent and are showing a tremendous rate of industrial development, mostly on the lines of North-American and European countries, the U.S.S.R. and Japan. Therefore, the need for energy is very urgent in these developing countries, and national policies and their relation to other countries are sometimes based on energy requirements, chiefly nuclear. Hydro-electric and coal or oil-fired stations are located very far from load centres for various reasons which requires the transmission of the generated electric power over very long distances. This requires very high voltages for transmission. The very rapid strides taken by development of dc transmission since 1950 is playing a major role in extra-long-distance transmission, complementing or supplementing e.h.v. ac transmission. They have their roles to play and a country must make intelligent assessment of both in order to decide which is best suited for the country's economy. This book concerns itself with problems of e.h.v. ac transmission only.

PROBLEMS OF EHV TRANSMISSION

(1)Corona loss & radio interference

When the potential difference between the conductors of an overhead transmission system exceeds a certain definite value (the visual critical voltage of the line) a hissing sound is heard, and the conductors are found to be surrounded by a lum- inous envelope to which the name corona has been applied (Waddicor, 1928). The luminous envelope is composed of air which has broken down and become temporarily conducting under the high electro- static stress, and its effect is equivalent to increasing the diameter of the conductors., The breakdown starts first near the surface of the conductor, as the electrostatic stress or potential gradient has its maximum value there, and the thick- ness of the conducting layer of air increases with an increase of potential difference. If the conductors are very close together the formation of corona involves an increase in the potential gradient between them; the corona spreads farther, the process continues until flashover occurs, In this case immediate dis- ruption takes place, and no stable corona can be formed.

(2)Erection & transportation difficulty

EHV transmission lines have large mechanical loading on towers because of use of bundled conductors, large air & ground clearance. Problems of erection & transportation arise as the supporting structures are to be transported over long distances and high standard workman-ship is required for erection of EHV transmission lines.

(3)Insulation requirement

The major aspect in designing a power transmission line is choosing its insulation level which has a considerable influence on the cost as well as operating reliability. The influence of EHV systems is determined on the basis of possible internal and external over -voltages. The recent advancements achieved in the design of circuit breakers and other protective devices have reduced the severe effects of switching transients and power frequency over-voltages allowing considerable reductions in the insulation level of EHV networks. The earthing of the system also plays an important role in reducing the insulation. Reduced insulation level results in large swing in the size and cost of equipment. The system over-voltage factors are therefore to be evaluated carefully while choosing the insulation levels.

Or

Q.1 Explain the phenomenon of corona & factors affecting corona? 10

Ans. Phenomenon of Corona:-

Electric transmission lines can generate a small amount of sound energy as a result of corona. Corona is a phenomenon associated with all transmission lines. Under certain conditions, the localized electric field near energized components and conductors can produce a tiny electric discharge or corona that causes the surrounding air molecules to ionize, or undergo a slight localized change of electric charge. Utility companies try to reduce the amount of corona because in addition to the low levels of noise that result, corona is a power loss, and in extreme cases, it can damage system components over time. Corona occurs on all types of transmission lines, but it becomes more noticeable at higher voltages (345 kV and higher). Under fair weather conditions, the audible noise from corona is minor and rarely noticed. During wet and humid conditions, water drops collect on the conductors and increase corona activity. Under these conditions, a crackling or humming sound may be heard in the immediate vicinity of the line. Corona results in a power loss. Power losses like corona result in operating inefficiencies and increase the cost of service for all ratepayers; a major concern in transmission line design is the reduction of losses.

Factors Affecting Corona:-

The phenomenon of corona is affected by the physical state of the atmosphere as well as by the conditions of the line. The following are the factors upon which corona depends:

(i) Atmosphere

As corona is formed due to ionsiation of air surrounding the conductors, there-fore, it is affected by the physical state of atmosphere. In the stormy weather, the number of ions is more than normal and as such corona occurs at much less voltage as compared with fair weather.

(ii) Conductor size

The corona effect depends upon the shape and conditions of the conductors. The rough and irregular surface will give rise to more corona because unevenness of the surface decreases the value of breakdown voltage. Thus a stranded conductor has irregular surface and hence gives rise to more corona that a solid conductor.

(iii) Spacing between conductors

If the spacing between the conductors is made very large as compared to their diameters, there may not be any corona effect. It is because larger distance between conductors reduces the electro-static stresses at the conductor surface, thus avoiding corona formation.

(iv) Line voltage

The line voltage greatly affects corona. If it is low, there is no change in the condition of air surrounding the conductors and hence no corona is formed. However, if the line voltage has such a value that electrostatic stresses developed at the conductor surface make the air around the conductor conducting, then corona is formed.

Q.2 Explain Following

(a) Surge impedance loading **5**

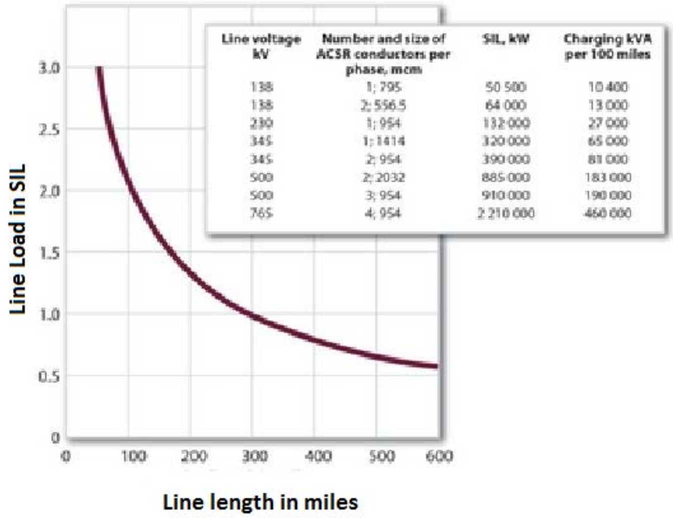
(b) Audio & Radio Noise **5**

Ans. (a) SURGE IMPEDANCE LOADING

The surge impedance loading or SIL of a transmission line is the MW loading of a transmission line at which a natural reactive power balance occurs. The following brief article will explain the concept of SIL.

Transmission lines produce reactive power (Mvar) due to their natural capacitance. The amount of Mvar produced is dependent on the transmission line's capacitive reactance (XC) and the voltage (kV) at which the line is energized. Transmission lines also utilize reactive power to support their magnetic fields. The magnetic field strength is dependent on the magnitude of the current flow in the line and the line's natural inductive reactance (XL). It follows then that the amount of Mvar used by a transmission line is a function of the current flow and inductive reactance.

A transmission line's surge impedance loading or SIL is simply the MW loading (at a unity power factor) at which the line's Mvar usage is equal to the line's Mvar production. In equation form we can state that the SIL occurs If we take the square root of both sides of the above equation and then substitute in the formulas for XL (=2pfL) and XC (=1/2pfC) we arrive at:



Line voltage kV	Number and size of ACSR conductors per phase, mcm	SIL, kW	Charging kVA per 100 miles
138	1; 795	50 500	10 400
138	2; 556.5	64 000	13 000
230	1; 954	132 000	27 000
345	1; 1414	320 000	65 000
345	2; 954	390 000	81 000
500	2; 2032	885 000	183 000
500	3; 954	910 000	190 000
765	4; 954	2 210 000	460 000

Fig: 1.1Surge impedance loading effect

The term $\sqrt{\frac{L}{C}}$ in the above equation is by definition the "surge impedance. The theoretical significance of the surge impedance is that if a purely resistive load that is equal to the surge impedance were connected to the end of a transmission line with no resistance, a voltage surge introduced to the sending end of the line would be absorbed completely at the receiving end. The voltage at the receiving end would have the same magnitude as the sending end voltage and would have a phase angle that is lagging with respect to the sending end by an amount equal to the time required to travel across the line from sending to receiving end.

The concept of a surge impedance is more readily applied to telecommunication systems than to power systems. However, we can extend the concept to the power transferred across a transmission line. The surge impedance loading or SIL (in MW) is equal to the voltage squared (in kV) divided by the surge impedance (in ohms). In equation form:

$$\text{SIL (in MW)} = \frac{kV_{L-L}^2}{\text{Surge Impedance}}$$

Note in this formula that the SIL is dependent only on the kV the line is energized at and the line's surge impedance. The line length is not a factor in the SIL or surge impedance calculations. Therefore the SIL is not a measure of a transmission line's power transfer capability as it does not take into account the line's length nor does it consider the strength of the local power system.

The value of the SIL to a system operator is realizing that when a line is loaded above its SIL it acts like a shunt reactor - absorbing Mvar from the system - and when a line is loaded below its SIL it acts like a shunt capacitor - supplying Mvar to the system.

Figure 1.2 is a graphic illustration of the concept of SIL. This particular line has a SIL of 450 MW. Therefore is the line is loaded to 450 MW (with no Mvar) flow, the Mvar produced by the line will exactly balance the Mvar used by the line.

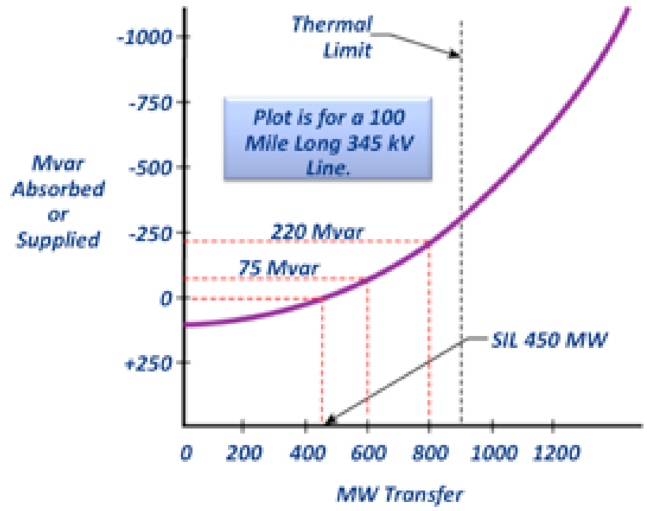


Figure 1.2 Surge Impedance Loading of a Transmission Loading

(b) Audio & Radio Noise

When corona is present on the conductors, e.h.v. lines generate audible noise which is especially high during foul weather. The noise is broadband, which extends from very low frequency to about 20 kHz. Corona discharges generate positive and negative ions which are alternately attracted and repelled by the periodic reversal of polarity of the ac excitation. Their movement gives rise to sound-pressure waves at frequencies of twice the power frequency and its multiples, in addition to the broadband spectrum which is the result of random motions of the ions, as shown in Figure 5.5. The noise has a pure tone superimposed on the broadband noise. Due to differences in ionic motion between ac and dc excitations, dc lines exhibit only a broadband noise, and furthermore, unlike for ac lines, the noise generated from a dc line is nearly equal in both fair and foul weather conditions. Since audible noise (AN) is man-made, it is measured in the same manner as other types of man-made noise such as aircraft noise, automobile ignition noise, transformer hum, etc.

LIMITS FOR AUDIBLE NOISE

Since no legislation exists setting limits for AN for man-made sources, power companies and environmentalists have fixed limits from public-relations point of view which power companies have accepted from a moral point of view. In doing so, like other kinds of interference, human beings must be subjected to listening tests. Such objective tests are performed by every civicminded power utility organization. The first such series of tests performed from a 500-kV line of the Bonneville Power Administration in the U.S.A. is known as Perry Criterion. The AN limits are as follows:

No complaints : Less than 52.5 dB (A),

Few complaints : 52.5 dB (A) to 59 dB (A),

Many complaints : Greater than 59 dB (A),

LIMITS FOR RADIO INTERFERENCE FIELDS

Radio Interference (RI) resulting from a transmission line is a man-made phenomenon and as such its regulation should be similar to other man-made sources of noise as mentioned in Chapter 5, such as audible noise, automobile ignition noise, aircraft noise, interference from welding equipment, r–f heating equipment etc. Some of these are governed by *IS* 6842. Legislation for fixing limits to all these noise sources is now gaining widespread publicity and awareness in public in order to protect the environment from all types of pollution, including noise. Interference to communication systems is described through Signal-to-Noise Ratio designated as *S/N* Ratio, with both quantities measured on the same weighting circuit of a suitable standard meter. However, it has been the practice to designate the signal from a broadcast station in terms of the average signal strength called the Field Intensity (FI) setting of the field-strength meter, while the interference signal to a radio receiver due to line noise is measured on the Quasi-Peak (QP) detector circuit. The difference in weighting circuits will be discussed later on. There are proposals to change this custom and have both signal and noise measured on the same weighting circuit. This point is mentioned here in order that the reader may interpret *S/N* ratios given by public utility organizations in technical literature or elsewhere since interference problems result in expensive litigations between contesting parties.

Or

Q.2 What is bundled conductor? Describe properties of bundled conductor & also formulate the GMR of bundled conductor. 10

Ans. BUNDLED CONDUCTORS:-

Bundled Conductors are used in transmission lines where the voltage exceeds 230 kV. At such high voltages, ordinary conductors will result in excessive corona and noise which may affect communication lines. The increased corona will result in significant power loss. Bundle conductors consist of three or four conductors for each phase. The conductors are separated from each other by means of spacers at regular intervals. Thus, they do not touch each other. Bundled conductors have higher capacity (current carrying capacity) as compared to ordinary conductors for a given weight. This is due to the reduced influence of the skin effect.

The reactance of bundled conductors is also lesser than single conductors. However, bundled conductors experience greater wind loading than single conductors.

Fig. 1.3 Bundled conductors

PROPERTIES OF BUNDLED CONDUCTORS:-

- Bundled conductors per phase reduces the voltage gradient in the vicinity of the line. Thus reduces the possibility of the corona discharge. (Corona effect will be observed when the air medium present between the phases charged up and start to ionize and acts as a conducting medium. This is avoided by employing bundled conductors)
- Improvement in the transmission efficiency as loss due to corona effect is countered.
- Bundled conductor lines will have higher capacitance to neutral in comparison with single lines. Thus they will have higher charging currents which helps in improving the power factor.
- Bundled conductor lines will have higher capacitance and lower inductance than ordinary lines they will have higher Surge Impedance Loading $(Z=(L/C)^{1/2})$. Higher Surge Impedance Loading (SIL) will have higher maximum power transfer ability.
- With increase in self GMD or GMR inductance per phase will be reduced compared to single conductor line. This results in lesser reactance per phase compared to ordinary single line. Hence lesser loss due to reactance drop.

GEOMETRIC MEAN RADIUS OF BUNDLE CONDUCTORS:-

So far we have considered only solid round conductors. Stranded conductors are used in practical transmission line. We must therefore modify the equations derived above to accommodate stranded conductors. Consider the two groups of conductors shown in **Fig. 1.3**. Of these two groups conductor x contains n identical strands of radius r_x while conductor y contains m identical strands of radius r_y. Conductor x carries a current I the return path of which is through conductor y. Therefore the current through conductor y is $-I$.

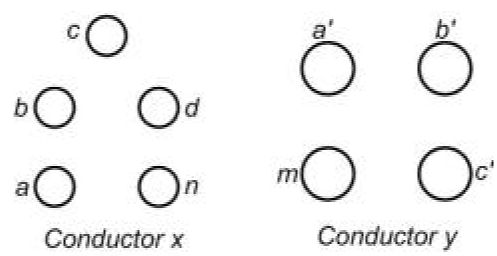


Fig. 1.4 Single-phase line with two composite conductors.

Since the strands in a conductor are identical, the current will be divided equally among the strands. Therefore the current through the strands of conductor x is I / n and through the strands where the **geometric mean distance** (GMD) and the **geometric mean radius** (GMR) are given respectively by the inductance of the conductor y can also be similarly obtained. The geometric mean radius GMR_y will be different for this conductor. However the geometric mean distance will remain the same.

Example-2:-Find the self GMD for each conductor configuration shown in Figure below

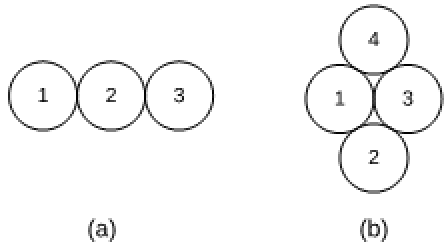


Fig1.5:- Bundles

Solution:-

(a). $GMR = \sqrt[3]{GMR1 \times GMR2 \times GMR3}$

$GMR1 = GMR3 = \sqrt[3]{0.7788r \times 2r \times 4r} = 1.84r$

$GMR2 = \sqrt[3]{0.7788r \times 2r \times 2r} = 1.4604r$

$GMR = \sqrt[3]{1.84r \times 1.4604r \times 1.84r} = \mathbf{1.7036r}$

(b). $GMR1 = GMR3 = \sqrt[4]{0.7788r \times 2r \times 2r \times 2r} = 1.5798r$

$GMR2 = GMR4 = \sqrt[4]{0.7788r \times 2r \times 2r \times \sqrt{12}r} = 1.8124r$

$GMR = \sqrt[4]{1.5798r \times 1.5798r \times 1.8124r \times 1.8124r} = \mathbf{1.6921r}$