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Vibration Damping in Overhead Transmission Line Conductors

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Fatigue is a common cause for failure of conductors near associated hardwares and attachment. Vibrations due to wind is a common cause for fatigue and frettingof conductors. Conductors under the effect of high frequency and low amplitude are more prone to vibrations particularly in India and other parts of the world. ACSR conductors have been a popular choice for overhead conductors due to advantages in both electrical and mechanical characteristics and these conductors are more prone to Aeolian vibrations. Vibration dampers are widely used to control Aeolian vibration of the conductors and earthwires including optical ground wires. In this paper the author presents the performance of vibration dampers on ACSR conductors. The author emphasizes the importance offor evaluating the suitability of a damper for a particular overhead line by choosing appropriate design tension, type, quantity and placement of vibration dampers to avoid failure of lines.

Keywords: *Aeolian vibration, Fatigue,Vibration dampers, conductors, earthwires, OPGW Power dissipation etc.*

1.0 INTRODUCTION

The major factors which affect the performance of the line components and its hardwares are caused by natural wind resulting in damages or failure of various components which may results in power disruptions and forced outages. Wind induced vibrations or Aeolian vibrations of transmission line conductors is a common phenomenon under smooth wind conditions. The cause of Aeolian vibration is due to vortex shedding across the leeward side of the conductors. The vortex shedding leads to pressure imbalances which arise due to alternate lift and drag forces along the length of the conductors which creates imbalances and causes the conductors to vibrate at right angle to the direction of air flow. The conductor vibration results in cyclic bending of he attached hardwares and near the portions where the movements is being restrained by the clamps and consequently causes conductor fatigue and breakage of the strands. The first sign of conductor damage is usually a broken strand under the hardware attachment clamps (Figure 1)

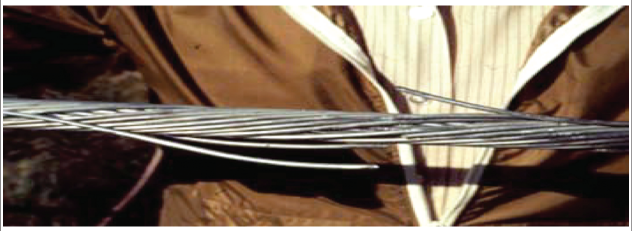

FIG. 1 VIEW OF BROKEN STRANDS OF CONDUCTORS

In recent years,AAAC (All Aluminum Alloy conductors) has been a popular choice for a transmission lines due to its high electrical carrying capacity and high mechanical tension to mass ratio.

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Unfortunately the self- damping of conductors decreases as tension increases. The wind power into the conductor increases with the span length. Hence AAAC conductors are likely to experience more severe vibrations than ACSR.

The “Stockbridge” type vibration damper is commonly used to control vibration of overhead transmission line conductors and OPGW. The vibration damper has a length of steel messenger cable. Two metallic asymmetrical weights are attached to the two ends of the messenger cables. The center clamp which is attached to the messenger cable is used to install the vibration damper onto the overhead conductor (Figure 2). The asymmetrical vibration damper is a multi-resonance system with inherent damping. The more the variation in weight, the more will be the damping property.

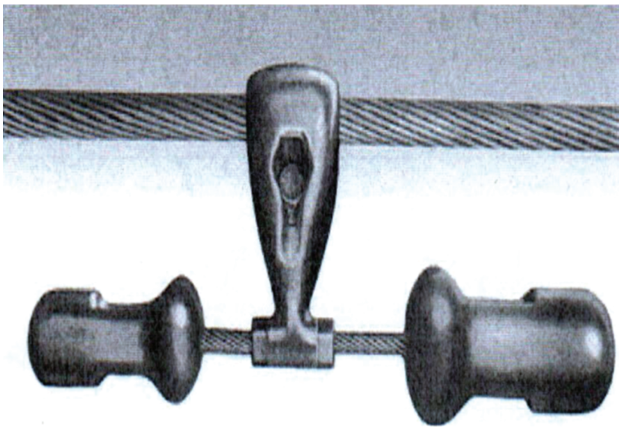

FIG. 2A STOCK BRIDGE VIBRATION DAMPER

FIG. 2B ONLINE VIEW OF VIBRATION DAMPER IN OVER TRANSMISSION LINES

The frequency of vibration of the conductor is proportional to the wind velocity and inversely proportional to the diameter of the conductor as given below

$$f = 0.185\frac{V}{D} \quad ....(1)$$

where,

f= frequency in Hz

V= Wind velocity perpendicular to the conductor m/s

D= Diameter of the conductor in mm.

Therefore smaller the diameter of he conductor higher will be the frequency of vibration and more the diameter of the conductor lower will be the frequency of conductor vibration.

Also frequency of vibration will get higher under high wind velocity and vice-versa. Thus the vibration damper should meet the requirement of wind velocity, the diameter of the conductor.

For the efficient use of vibration damper, it needs to be installed at a suitable position to ensure effectiveness across the frequency range. The power dissipation in the vibration damper should exceeds the wind power, so as to suppress the level of vibration on the conductor below its endurance limit. The endurance limit was derived by fatigue tests on conductor for ACSR [4].

The factors which affects the level of vibration on the conductor are geometry of the conductor, the terrain conditions from where the line is passing, tension on the conductor, the wind speed acting on the conductor, the atmospheric conditions, the suspension type and the span length. Open flat terrain is most favorable to conductor vibration. Hence in the situation of high tension and open flat terrain it is of utmost importance to ensure the conductor is protected by an adequate number of vibration dampers.

The method of evaluating the performance of Stockbridge damper includes analytical method, field method amd laboratory test method. The analytical method uses line design data and mechanical impedance of the vibration damper. The field test is in general accordance with cigre guide [5]. The laboratory test method utilizes a minimum of 30 m conductor span [1].

2.0 GENERAL TEST SET-UP

The test shall be conducted indoor laboratory set up with a minimum span of length of 30 meter and in still air. The ambient temperature during the test should be constant during the span and during the measurements. During the test the tension variation should not be exceed ±2 percent of rated tensile strength value. The test set-up is shown in the (Figure 3), which is in general accordance with IS-9708:1993.

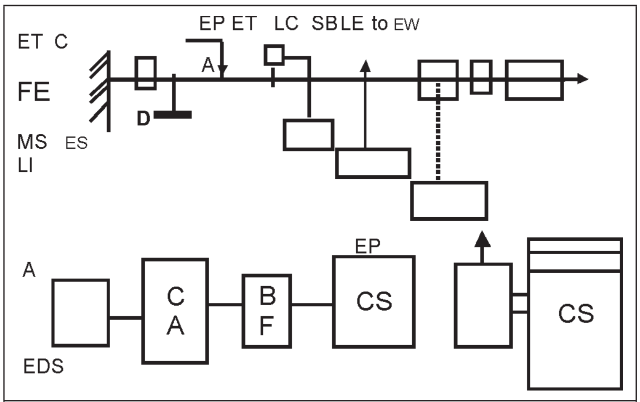

FIG. 3 TEST ARRANGMENTS BLOCK DIAGRAM SHOCKING

MEASUREMENT SET UP

FE - FIXED END

D - DAMPER

A - ACCELEROMETER

EP - EXCITATION POINT

ET - END TERMINAL

LI - LOAD INDICATOR

BF - BAND PASS FILTER

EDS - ELECTRO DYNAMIC SHAKER

EW - ELECTRICAL WINCH

EXCITATIONSET UP

C - CONDUCTOR

MS - MEASURING SYSTEM

ES - EXCITATION SYSTEM

LC - LOAD CELL

SB - SHEAVE PULLEY BLOCK

CA - CHARGE AMPLIFIER

OS - OSCILLOSCOPE

CS - CONTROL SYSTEM

LE - LOADING END

The conductor shall be tensioned at 25 percent of its nominal ultimate tensile strength. Before starting, the conductor should be conditioned by holding it at least for a period of two hours at 25 percent of its UTS, so as to avoid bending of the conductors through a sharp radius of curvature where it normally enters the clamp.

3.0 EXPERIMENTATION

The conductor (span) shall be vibrated sinusoidally by an electrodynamic shaker system. The shaker system shall be vibrated through a functional generator with high resolution, so that it should be vibrated at multiple loops which can be viewed through a suitable data acquisition system, if the phase angle between the force and velocity is 90 deg. The ACSR moose conductor is rigged at 40 meter test span and the tension provided was 25 percent of rated tensile strength. The assymetrical vibration damper is placed at 1.3 m to 1.5 m from the test span where the torque applied was 6 kg-m (approx.). The power of shaker system was adjusted at frequencies of 5 Hz to 43 Hz. The axis of vibration was vertical throughout the measurement.

PARAMETERS

Diameter - 31.77

Span length - 38.5 m

Rated Tensile Strength - 159.71 kN

Tension - 25% of RTS

Mass - 2.0015 kg/m

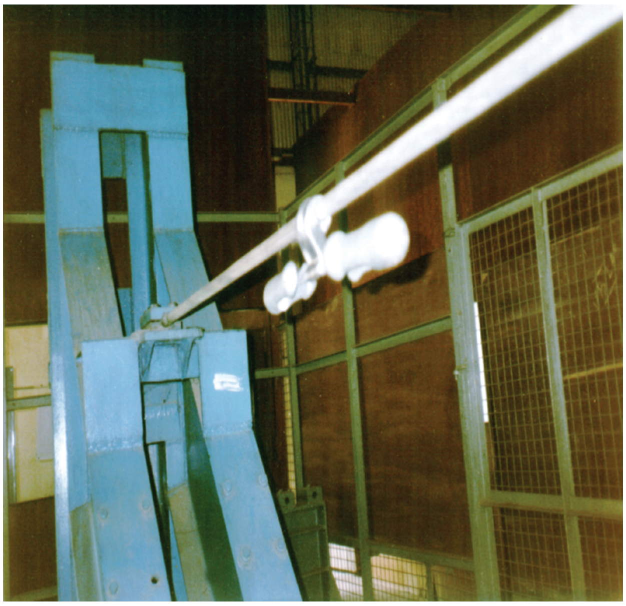

FIG. 4 DAMPER ATTACHED ON RE CONDUCTOR UNDER TEST

4.0 RESULTS AND OBSERVATIONS

From vibration analysis of conductor withdamper(s) installed at the recommendedlocation, the dynamic strain level at the clampedspan extremities, damper attachment pointand the antinodes as well as damper clampvibration amplitude and antinode vibrationamplitude shall be determined [4-7]. The values sodetermined shall not exceed the specified limits.

Efficiency of Damper can be calculated by:

$$\eta = \frac{NA}{ANA} x100 \% \quad ....(2)$$

The conductor dissipation power is primarily a function of mechanical impedance which is given by Figure 5.

$$P_c = \sum_5^{43} [sqrt(Z) * sqr(w) * sqr(ANA/2)] \text{ W} \quad ....(3)$$

The wind power input transferred from the wind to a vibrating conductor can be expressed in the form, which is basically a function of amplitude and frequency of the vibrating conductor.

$$P_w = \sum_5^{43} (l * f^x D^y f(a/D)) \text{Watt} \quad ....(4)$$

FIG. 5 VIEW DYNAMIC STABLE SYSTEM UNDER TEST

Z – Mechanical impedance (kg-m)

W – 2πf

NA – Nodal amplitude (mm)

ANA – Antinodal amplitude (mm)

NA – Nodal amplitude (mm)

f – Frequency (Hz)

D – Diameter of the conductor (mm)

a – Amplitude (mm)

ι – Span length (m)

P_c – Power dissipation by the conductor (watt)

P_w – Power imparted by the wind to the conductor (watt)

x & y – variable values [7]

The efficiency results shown in (Figure 6) represents that in the frequency range of 5 Hz to 43 Hz, the observed curve of the Stockbridge damper is well above the acceptance curve of the damper.

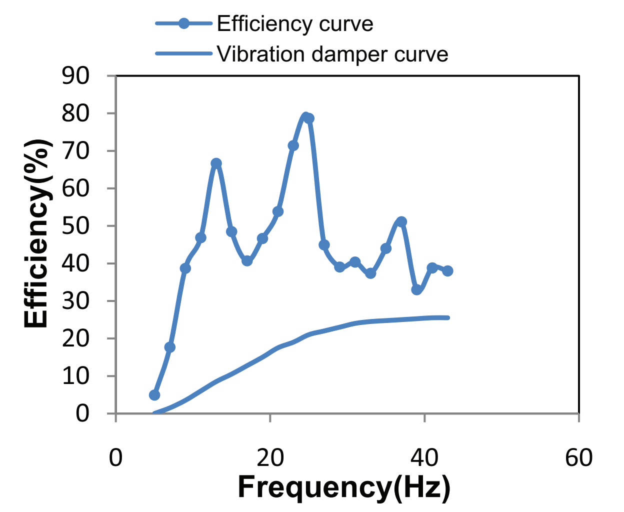

FIG. 6 EFFICIENCY CURVE OF DAMPER

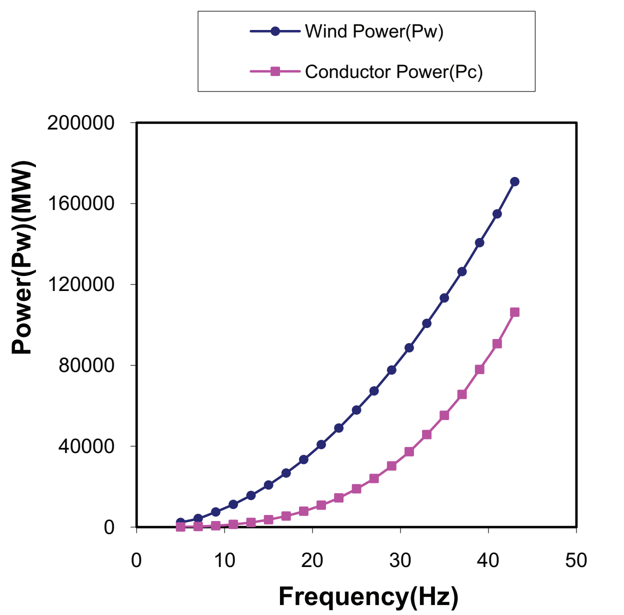

FIG. 7 POWER CURVE OF A DAMPER W.R.T. FREQUENCY

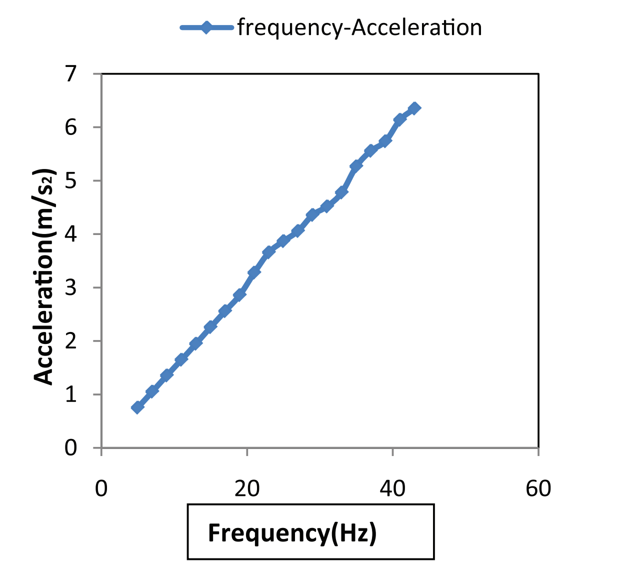

FIG. 8 ACCELERATION CURVE W.R.T. FREQUENCY

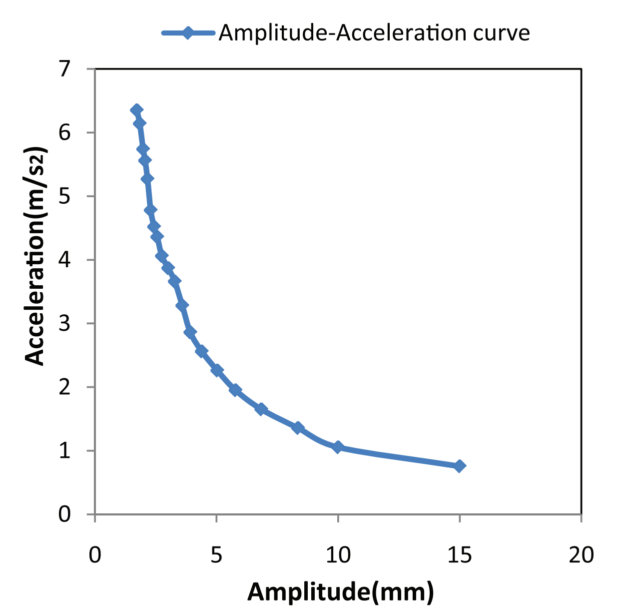

FIG. 9 ACCELERATION CURVE W.R.T. AMPLITUDE OF DAMPER VIBRATION

5.0 CONCLUSION

The acceptance curve is as per Indianstandard (Figure 6). The result shows that the efficiency of the 4R vibration damper exceeded the acceptance curve in the frequency range of 5 Hz to 43 Hz which qualifies the damper efficiency test and acceptable of the dissipation characteristics for the field purpose. The graph in (Figure 7) expresses the fact that if the frequency of vibration goes on increasing the power transmitted by the wind to the conductor also increases also the function of amplitude with respect to the diameter is very sensitive to disturbances such that the increase in turbulence level decreases the wind power input. Also the frequency of vibration increases with the acceleration level of the vibrating conductor and consequently the amplitude of displacement goes on decreasing with the increase in the conductor acceleration. The power dissipation required by the damper should always be either greater than or equal to the wind power imparted to the conductor. If this energy balance condition does not exists then the design of the vibration damper should be modified as per the geometry of the conductor, the terrain conditions from where the line is passing, tension on the conductor, the wind speed acting on the conductor, so as to qualify as per the acceptance criteria and also for the dissipation characteristics of the Vibration damper.

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