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# भारतीय रेल विद्युत इंजीनियरिंग संस्थान, नासिक रोड

Indian Railways Institute of Electrical Engineering, Nasik Road

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भारतीय रेल विद्युत विभाग की पूर्ण रूप से एकमात्र तकनीकी पत्रिका

## (रेल विद्युत कार्यालयों में नि:शुल्क वितरण हेतु)

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लेखों में दिये गये विचार लेखक के हैं, इरीन के नहीं।

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# परिचय

अपरिहार्य कारणों से इरीन जर्नल का प्रकाशन समय पर नहीं हो सका इसके लिए हमें खेद है। किन्तु इरीन जर्नल के प्रति आपका लगाव एवं सराहनीय प्रशंसा हमें इसको और महत्वपूर्ण व उपयोगी बनाने की प्रेरणा देती है। हम अपने पाठकों एवं प्रशंसकों को विश्वास दिलाते हैं कि इसको और अधिक रोचक एवं महत्वपूर्ण तकनीकी जानकारियों के साथ सुचारु रूप से जारी रखने का प्रयास करेंगे।

इरीन संस्थान द्वारा प्रकाशित इस अंक में निम्न विषयों पर तकनीकी जानकारी प्रस्तुत की जा रही है।

1. **प्रथम लेख में** **BASICS AND AN INSIGHT OF PANTODYNAMICS-**
   पर मूलभूत जानकारी उपलब्ध कराई गई है।

2. **द्वितीय लेख में** **CB TRIPPINGS: ANALYSIS AND AVOIDANCE-**
   पर आवश्यक जानकारी उपलब्ध कराई गई है।

3. **तृतीय लेख में** **BULLET TRAIN: AN INSIGHT INTO HIGH-SPEED ELECTRIC TRACTION-**
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4. **चतुर्थ लेख में** **MOBILE APPLICATION FOR OHE CANTILEVER DESIGN-**
   पर आवश्यक जानकारी उपलब्ध कराई गई है।

5. **पंचम लेख में** **हिंदी संस्करण-**
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   **(घ) फोटो गैलरी –** इरीन की गतिविधियां

IRIEEN JOURNAL

# BASICS AND AN INSIGHT OF PANTODYNAMICS



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## Abstract:

This article tries to put forward the basics of various kind of waves that come into the picture when a train is running on an electrified line. These waves are a result of the dynamic interaction of the pantograph and the overhead wire. Based on these interactions, there are certain dynamic parameters of the overhead wire. These dynamic parameters are very important since they determine the limits above which a particular OHE is not capable of providing current to the pantograph. In other words, the pantograph becomes incapable of collecting the current. The main focus is put on the parameters in the Indian context.

**Index terms –** Doppler Coefficient, Amplification Coefficient, Reflection Coefficient, Fluctuation propagation constant, Travelling waves.

## 1. INTRODUCTION

The development of a fast-growing nation like India is directly linked with the developments of Indian Railways, which is rightly suffixed with 'Lifeline of the Nation'. According to several reports, the growth of an economy is directly proportional to the speed of Railways. The International Union of Railways (UIC) says high-speed rail (HSR) is a train with an operating speed of 200km/hour for an existing system and 320 km/h on new construction. In the early 20th century, trains only reached 200 km/h at maximum speed. When Japan's Shinkansen system opened in 1964, it was the first train when a 200 km/h operation speed was used. For high-speed trains, the perfect contact between pantograph and electric wire is tough to achieve. According to Tiago's study "Dynamics and Control of a High-Speed Train Pantograph System", the contact force variation can cause the contact force variation can cause contact losses, electric arc formations and spark[6]. This deteriorates the current collection quality and increases the electrical related wear, therefore becoming a limiting factor for the maximum train speed [2][3]. The increase of the static contact force is not an efficient way to deal with the problem because it increases mechanical abrasive wear and produces an excessive uplift of the contact wire. While the train operates on the rail at high speeds, reactions between catenary and pantograph make a complex coupling vibration system. This article aims to bring forward a basic understanding of these interactions involved.

## 2. PROPAGATION OF VIBRATIONS ALONG CONTACT WIRE

To begin with, let us go to the reason for this vibration. Why shall there be vibrations at all? The answer to this question needs us to revisit our fundamental physics of school.

The contact wire is made up of a material, the details of which is presented in later subheadings. Now this material, by virtue of its property, has some elasticity. Because of its elasticity, the molecules of the material tend to remain in a fixed position. Now, when the pantograph lifts the catenary, the molecules in contact with the

pantograph lift up, causes the surrounding molecules also to lift, although at a relatively lower height. So, there are two forces in picture [1]:

1. The inertia of the pantograph

2. The elasticity of the material of the contact and catenary wire

The interaction of this elasticity and inertia leads to vibrations in the wire. The result of this interaction is the formation of a wave. Since the wave movement is perpendicular to the direction of molecules, it is a transverse wave. This wave, if not managed properly, may cause damage to the arrangement of the overhead lines and to pantograph also.

Fig 1 given describes the nature of the wave.

Fig 1A: shows the initial state of contact wire under pantograph uplift force $F_0$

Fig 1B: shows the initial transverse view of the contact wire propagated along with the contact while after the uplift force of the pantograph at the moment of the initial state(t=0)

Fig 1C: shows the propagation of the wave at a specific position on the contact wire forward and backward of the pantograph at (t+δt).

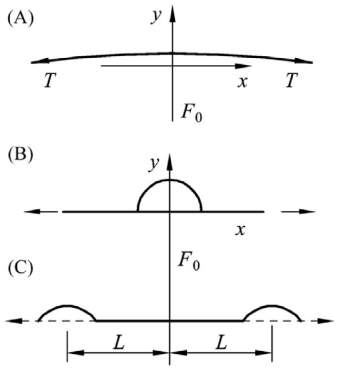



Fig 1: (A) initial stage of contact wire (B) initial state of transverse wave (C) Propagation of transverse-wave

Under the action of the pantograph, a wave is propagated along the contact wire into two directions, and amplitude attenuates over time. Moreover, from the propagation process of the way when an electric train has several pantographs for current collection, the contact quality of the pantograph and overhead contact line will deteriorate if the rear pantograph faces a wave formed by a vibration from the front pantograph. The Indian OHE is designed for three pantographs working simultaneously.

## 3. STRESS ANALYSIS OF A MICRO SECTION OF CONTACT WIRE

As shown in fig 2, The shape of the contact wire is symmetrical about the point of its contact with the pantograph when the train is in a fixed position. However, when the train moves with a velocity v along the right direction, the shape of the contact wire distorts. Now for understanding the dynamics of the propagation of a wave, we need to analyze a micro section of the the contact wire and authors acknowledge [1] for various mathematical derivations of this paper.

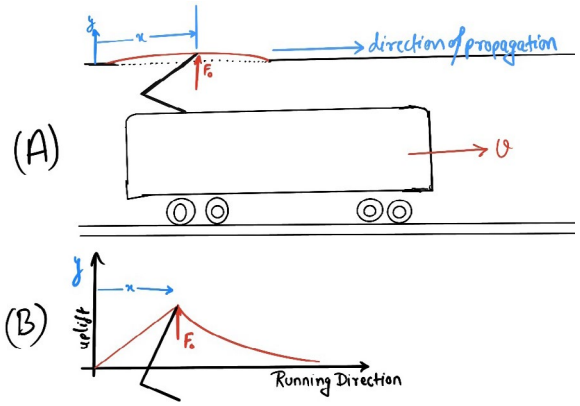



Fig 2: Diagram showing the shape of contact wire

The force $F_0$ can be understood like an external force in the system. For analyzing the properties and effects of this external force, the response may be divided into two parts first due to the inherent property of the system called 'natural response' and second is due to the external force applied to the system, i.e., 'forced response'. Fig 2A can be used to analyze the natural response, and fig 2B can be used to analyze the forced response.

### 3.1 NATURAL RESPONSE

For analyzing the natural response of the contact wire, let us consider when the force applied on the contact wire is static, as shown in figure 2A. If we see a micro section of the contact wire, Tension T acts on it, as shown in the given figure.

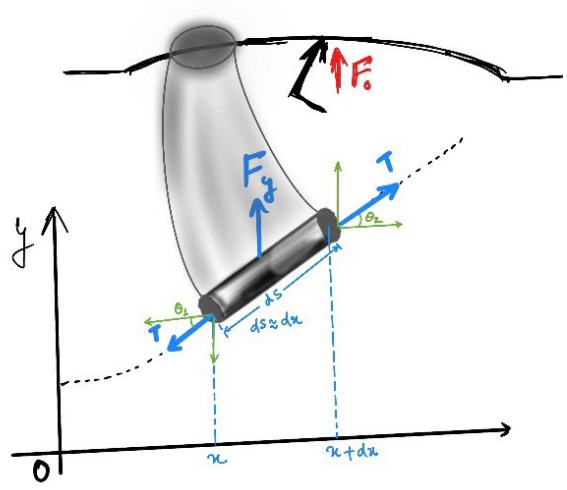



Fig 3: free body diagram of a micro section of a contact wire.

From the figure, the following set of equations can be written:

$$F_y = Tsin(\theta_2) - Tsin(\theta_1)$$

If $\theta$ is very small, $sin\theta_2 = tan\theta_2 = \left(\frac{\delta y}{\delta x}\right)_{x+\delta x}$ $and sin\theta_1 = tan\theta_1 = \left(\frac{\delta y}{\delta x}\right)_x$

Substituting it to the previous equation using taylor series expansion,

$$F_y = \left(T\frac{\delta y}{\delta x}\right)_{x+\delta x} - \left(T\frac{\delta y}{\delta x}\right)_x$$

$$= \frac{\delta}{\delta x}\left(T\frac{\delta y}{\delta x}\right)dx$$

$$or \quad = m.dx\frac{\delta^2 y}{\delta t^2}$$

so,

$$\frac{\delta}{\delta x}\left(T\frac{\delta y}{\delta x}\right)dx = m.dx\frac{\delta^2 y}{\delta t^2}$$

$$\frac{\delta^2 y}{\delta x^2} = \frac{m}{T}.\frac{\delta^2 y}{\delta t^2}$$

where, m=mass/length of contact wire.

If $C_p = \sqrt{\frac{T}{m}}$, we arrive at this equation

$$\frac{\delta^2 y}{\delta x^2} = \frac{1}{C_p^2}.\frac{\delta^2 y}{\delta t^2} \ldots\ldots \text{Eq1}$$

The constant $C_p$ in Equation 1, is known as the fluctuation propagation constant [1][2]. Equation 1 denotes the one-dimensional standard fluctuation equation of tension wire. Since it is a second-order partial differential equation with two variables, it represents an equation of a wave, in fact, a one-dimensional wave. This further proves the fact that the generation of a wave is an inherent property of the contact wire. This equation is the representation of the natural response of the system.

## 3.2 FORCED RESPONSE

Clearly, the vertical force along this micro-section may be written as: $F_y = T.dx\frac{\delta^2 y}{\delta x^2} + F_0' dx = T.dx\frac{\delta^2 y}{\delta x^2} + F_0' \delta(x - vt)dx$ where $F_0'$ is the force per unit length acting on the contact wire. Using newtons second law,

$$F_y = m.dx\frac{\delta^2 y}{\delta t^2}$$

So, $m.dx\frac{\delta^2 y}{\delta t^2} = T.dx\frac{\delta^2 y}{\delta x^2} + F_0'\delta(x - vt)dx$

or $\frac{\delta^2 y}{\delta t^2} = C_p^2.\frac{\delta^2 y}{\delta x^2} + \frac{F_0'}{m}\delta(x - vt)dx \ldots\ldots \text{Eq 2}$

Equation 2 describes the vibration state equation of the contact wires with total tension T and mass per unit length m under uplift force $F_0$ when the pantograph operates at speed v. It is the oscillatory differential equation of the contact wire.

We know that Total Response = Natural Response + Forced Response. So, equation 1 and equation 2 can be combined to find the final equation that describes the system's response. The calculations as stated above is shown in the Annexure, and the final equation arrived after these calculations is given as under:

$$y(x,t) = \frac{2F_0' l}{m\pi^2(C_p^2 - v^2)} \cdot \sum_{n=1}^{\infty} \frac{1}{n^2} \cdot sin\frac{n\pi x}{l}\left(sin\frac{n\pi v t}{l} - \frac{v}{C_p} sin\frac{n\pi C_p t}{l}\right) \ldots. \text{Eq 3}$$

where l is the length of the span considered [1].

## 4. INFERENCES FROM THE DIFFERENTIAL EQUATIONS OF CONTACT WIRE

The following inferences can be drawn from the equation of the response Eq 3:

1. The amplitude of deflection can be given by $y(x,t) = \frac{2F_0' l}{m\pi^2(C_p^2 - v^2)}$ and rest of the terms are eventually trigonometric terms which display the wave nature.

2. The deflection y of the wire is directly proportional to the force incurred by the pantograph. Therefore, the lower the force, the lower is the deflection. Because of this reason, the pantograph is raised generally with three steps so that the pantograph does not have an impact or an impulse or high jerk to the contact wire.

3. The deflection y seems to be inversely proportional to the mass per unit length of the contact wire. Therefore, the lower the mass, the higher is the deflection which means that if lighter materials are used, there are higher chances of deflection. However, this is not true. We need to substitute the value of the fluctuation propagation constant.

$$y(x,t) = \frac{2F_0' l}{m\pi^2(C_p^2 - v^2)} = \frac{2F_0' l}{m\pi^2(\frac{T}{m} - v^2)} = \frac{2F_0' l}{\pi^2(T - v^2 m)}$$

Clearly, $y \propto m \propto \frac{1}{T}$. So, for lower deflection, we need a contact wire of lower mass per unit length and higher tension.

4. What happens if the velocity with which the train operates reaches the fluctuation propagation constant?

$$y(x,t) = \lim_{v \to C_p} \frac{2F_0' l}{m\pi^2(C_p^2 - v^2)} = \infty$$

Therefore, there is a limit to which the train can operate. The speed of the train cannot be more than the fluctuation propagation constant. If the speed reaches nearby fluctuation propagation constant, the deviation tends to be infinite, ultimately current collection is not possible. So, to increase the train's speed, Cp has to be higher, i.e., the tension T needs to be improved.

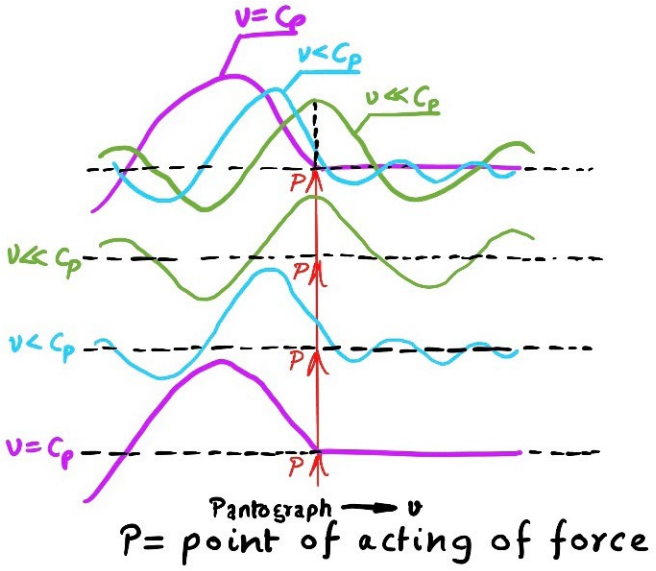



Fig 5: deflection of contact wire at different operating speeds of pantograph

5. Also, the deflection amplitude is directly proportional to the length of span l; therefore, the higher the span length, the higher the amplitude of deflection. So, we want the length of span to be minimum. However, this increases installation costs.

6. The frequency of oscillation is dependent on the term. A train with high velocity will have a high frequency of oscillations, and also, a lower span length will result in a higher frequency of oscillations.

## 5. FLUCTUATION PROPAGATION CONSTANT

The fluctuation propagation constant has quite a significant role in designing the overhead lines as it gives us the limit, or in other words, train has to run below this speed for proper current collection [1].

- When v << Cp, the wave has no noticeable change before and after point P, except for attenuation of

amplitude on the right of point P due to a damping effect. Uplift force rarely influences stress on the contact wire and pantograph and overhead contact line contact quality.

- When v < Cp and v are close to Cp, the wave changes (attenuates) obviously on the right of point P. In such a case, the uplift force has a certain influence on stress on the contact wire and pantograph and overhead contact line contact quality.

- When v = Cp (i.e., the moving speed of the pantograph is equal to the wave propagation speed), the contact wire has severe deflection at point P. The contact wire to the right of point P nearly becomes a straight line, and that on the left of point P has severe deflection. The uplift force has a very unfavourable impact on a pantograph and overhead contact line contact quality and contact wire stress.

Considering the factor of safety, the maximum speed of the train can be

$$v_{max} \leq \beta . C_p.$$

Where  is the safety limit, usually kept as 70% in Indian Railways.

## 6. WAVE REFLECTION AND ITS IMPACT ON OHE

When a transverse wave propagated along the contact wire meets a barrier (such as a concentrated mass and dropper), the wave will return and propagate along the contact wire. This is called wave reflection.

### 6.1 DOPPLER EFFECT

The diagram (Fig 6) clearly depicts the Doppler effect. Whenever there is a relative motion between the source and the observer, the frequency observed by the observer is different from the actual frequency of the source.

Before a moving wave source, the wave will be compressed, the wavelength will be shortened, and frequency will become higher; conversely, after a moving wave source, the wavelength will be increased, and frequency will become lower. The higher the wave source speed is, the more significant the generated effect will be. This is the so-called Doppler effect.

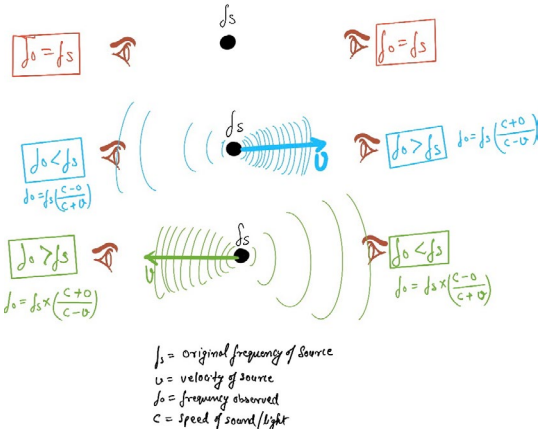



Fig 6: Diagram showing doppler effect

For overhead contact wires, the frequency is directly proportional to the velocity of movement of the particles. So, it can be concluded that equations, as described above, will be valid.

### 6.2 REFLECTION OF WAVE AT CONCENTRATED MASS

As shown in Fig. 7, a concentrated mass M is fixed rigidly at the $x=x_0$ position of the contact wire. For transverse propagation along the contact wire, after meeting M at $x_0$, it will generate a reflected and transmitted wave. A partial wave moves forward after passing through M, and the other part is reflected back. Fluctuation energy causes vibration of M. Its amplitude is expressed with $y_0(t)$; that is, $y_0(t)$ is the result of fluctuation action. Representing waves on the left and right of M using: $f_1(x_0 - C_p t)$ and $f_2(x_0 + C_p t)$ respectively, then,

$$y_0(t) = y(x_0, t) =$$
$$f_1(x_0 - C_p t) + f_2(x_0 + C_p t)^{[1]}.$$

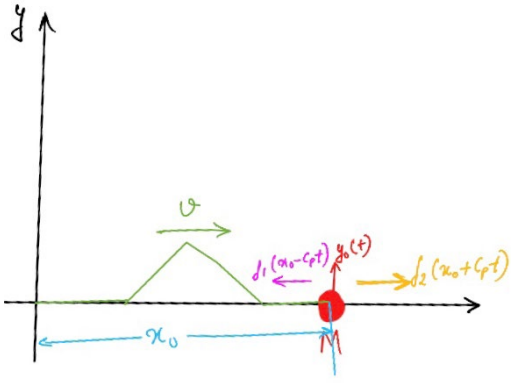


Fig 7: Concentrated mass met by wave

The aforesaid fluctuation change is equivalent to a counteracting force upon M. Such counteracting force is

$$F_r(t) = -2mC_p y_0' = -\frac{2T}{C_p} \cdot y_0'$$ where m means mass per unit length of the contact wire. Such counteracting force counteracts upon M due to elasticity relation. As a result, reflection on the contact wire is excited, and the reflection wave is contrary to the arriving wave. After introducing boundary condition, $y(x_0,t) \equiv 0$ the reflection of the contact wire can be expressed with the following differential equation:

$$m_c \frac{\delta^2 y}{\delta t^2} - T \frac{\delta^2 y}{\delta x^2} = q(x,t)$$ where q(x,t) is the linear load varying upon time.

At $x=x_0$, the concentrated mass M connected to the contact wire forms an interfering reflection against the incident wave. The wave arriving from the left is $y_0(t)= f(x_0-C_pt)$, which will generate an unknown counteracting force $F_r(t)$ at point M. Such force is applied to the contact wire in the opposite direction. Speed of the contact wire at $x=x_0$ is up to $y_r'(t)=F_r(t)/(2mC_p)$

Under the action of such force and another incoming vibration wave, both motions at such point are overlaid. The total speed at such a point is

$$\begin{aligned} y'(t) &= y_0'(t) + y_r'(t) \\ &= y_0'(t) \\ &\quad + F_r(t)/(2mC_p) \end{aligned}$$

At $x=x_0$, the motion of contact wire is identical to motion of mass point M. It can be expressed with this differential equation,

$$M \cdot y'' = -F_r(t).$$

.

Eliminating counteracting force $F_r(t)$ from two differential equations, the differential equation of motion at point $x_0$ is

$$M \cdot y'' + 2mC_p y' = 2mC_p y_0' \ldots. \text{Eq 4}$$

Incident wave $y_0(t)$ is known, so calculate $y(t)$ after quadrature of motion equation, and calculate the counteracting force:

$F_r(t)=2mC_p \cdot (y'-y_0')$ and additional speed component $y_r(t)=F_r(t)/(2mC_p)=y'-y_0'$ and additional motion component $y_r(t)=y(t)-y_0(t)$.

The motion component $y_r(t)$ is reflection wave

$$y_r\left(t + \frac{(x-x_0)}{C_p}\right).$$

If $\leq x_0$, $y_r$ is the wave transmitted on the left of mass point M; if $x \geq x_0$, $y_r$ is the wave transmitted on the right of mass point M, namely

$$\begin{aligned} & y\left(t - \frac{(x-x_0)}{C_p}\right) \\ &= y_0\left(t - \frac{(x-x_0)}{C_p}\right) \\ &\quad + y_r\left(t - \frac{(x-x_0)}{C_p}\right) \end{aligned}$$

If incident sine wave $y_0(t)=y_0 e^{jwt}$, the particular solution of Eq 4 will be

$$y(t) = \frac{y_0(1-\mu\omega)}{(1+\mu^2\omega^2).e^{j\omega t}}$$ where, $\mu = M/(2mCp)$.

Additional motion $y_r(t)$ is $y_r(t) = y(t) - y_0(t)$

Counteracting force is [1]:

$$F_r(t) = 2mC_p y'r(t) = y_0 M\omega^2 \frac{(1-j\mu\omega)}{(1+\mu^2\omega^2)} \cdot e^{j\omega t} \ldots. \text{Eq 5}$$

Reflection coefficient is :

$$r = \frac{y_r}{y_0} = -\frac{\mu\omega(j+\mu\omega)}{(1+\mu^2\omega^2)} \ldots..\text{Eq 6}$$

Eq 5 shows that the amplitude of counteracting force $F_r(t)$ at low frequency:

$$\lim_{\omega \to 0} F_r(t) = y_0 M\omega^2 .$$

At higher frequency, such amplitude will be

$$\lim_{\omega \to \infty} F_r(t) = \frac{y_0 M\omega}{\mu} = 2yC_p\omega,$$

which is in direct proportion to w. So, the reflection coefficient is –1. This means, for a wave with a very short wavelength, the action of the concentrated mass is like fixing the contact wire at such a point. The incident wave is fully reflected [1].

## 6.3 REFLECTION OF WAVE AT DROPPER

In catenary equipment, the contact wire and the catenary wire are connected via a dropper where the reflection of transverse wave occurs. It is assumed that the tension of the contact wire is $T_c$ and the tension of the messenger or catenary wire is $T_m$, unit masses of them are, respectively, $m_c$ or $m_m$ Dropper mass is M, and contact wire amplitude is $y_0\,(t\text{-}x/C_c)$ [1].

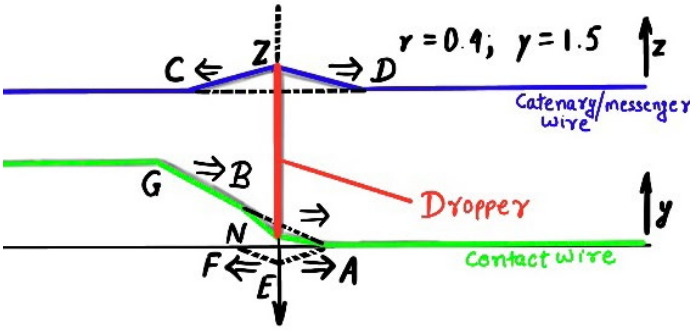
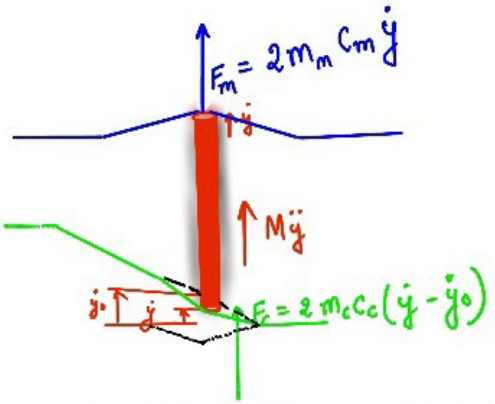



Fig 8: Moment before the meeting of vibration wave and dropper

If the incident wave meets the dropper at x = 0 from the left (Fig 8), the dropper will generate motion




$$M\ddot{y} + 2m_c C_c(\dot{y} - \dot{y}_0) + 2m_m C_m \dot{y} = 0$$
$$\text{or, } 2(m_c C_c + m_m C_m)\dot{y} + M\ddot{y} = 2m_c C_c \dot{y}_0$$

Fig 9: Free body diagram of dropper

$y_0(t)$. Due to motion y(t), the dropper counteracts such vibration wave to add a counteracting force $F_m=2m_m C_m \dot{y}$ to the standstill messenger wire and $F_c=2m_c C_c(\dot{y}-\dot{y}_0)$ to the contact wire as shown in Fig 9. In addition, inertial force $M\ddot{y}$ appears under the mass of the dropper. The motion equation of the dropper is

$$2(m_m C_m + m_c C_c)\dot{y} + M\ddot{y} = 2m_c C_c \dot{y}_0$$

where $C_c = \sqrt{\frac{T_c}{m_c}}$ and $C_m = \sqrt{\frac{T_m}{m_m}}$ are,

respectively, the fluctuation propagation speed of the contact wire and the catenary/messenger wire. This equation has the same form as Eq 4. For the incident sine wave $y_0(t)=y_0 e^{j\omega t}$, its particular solution is

$$y(t) = \frac{2m_c C_c}{2(m_c C_c + m_m C_m)y + Mj\omega} \cdot y_0 e^{j\omega t}.$$

Based on such solution, the reflected wave along the contact wire is

$$y_r(t) = y(t) - y_0(t) = \frac{-(2m_m C_m + Mj\omega)}{2(m_c C_c + m_m C_m) + Mj\omega} \cdot y_0 e^{j\omega t}$$

Due to the small mass of the dropper (including clamps on both ends), Mjω can be ignored at any frequency that is not too low. According to this assumption, without considering the dropper mass, the reflection coefficient of the wave is [1]:

$$r = -\frac{y_r}{y_0} = \frac{m_m C_m}{m_m C_m + m_c C_c} = \frac{\sqrt{T_m m_m}}{\sqrt{T_m m_m} + \sqrt{T_c m_c}} \quad \text{.....Eqn 7}$$

The dropper is usually made of a thin and flexible conductor and bears half the weight of the contact wire between adjacent droppers. If a dropper rises along the contact wire due to a vibration wave, the pull force will be weakened under the action of Fm − Fc. When the pull force becomes negative, the dropper will become slack. If the distance between droppers is $l_1$, gravity acceleration

is g, and the initial tension of the dropper is $m_c g l_1$, the dropper will become slack in the following condition:

$$(m_m C_m - m_c C_c)\dot{y}_0 + m_c C_c \dot{y}_0 \geq m_c g l_1 \ldots\ldots \text{Eq 8}$$

Combine Eq 7 and Eq 8 and assuming dropper mass M is 0. According to Eq 7, the slack condition of the dropper is:

$$2m_c C_c \dot{y}_0 \geq \frac{m_c g l_1}{r} \ldots\ldots\ldots\ldots \text{Eq 9}$$

It can be seen that the smaller the reflection coefficient is, the less possible it will be for the dropper to become slack due to the vibration of the contact wire[1]. The reflection coefficient is a mass property of the contact line. When mass per unit length and tension of the messenger wire are lower than those of the contact wire, the reflection coefficient will be small.

Fig.8 shows how dropper NZ reflects the incident wave. A square wave of pantograph force makes the contact wire generate straight wavefront GA with coefficient r = 0.4 and also shows the propagation of such wave in the contact wire and the messenger wire. Uplift of dropper NZ generates wavefront NA in the contact wire on the right of the dropper (within the propagation range). Wavefront ZD generated in the messenger wire is also propagated rightward. ZC is symmetric to ZD and moves leftward. In the contact wire, reflection wave EF will overlay onto the incoming wavefront GA, leading to sharpening of the gradient of the BN section of the contact wire. Wavefront NA can be deemed superposition of BA before the fundamental wave and wavefront EA and is symmetric to wavefront EF [1] [3].

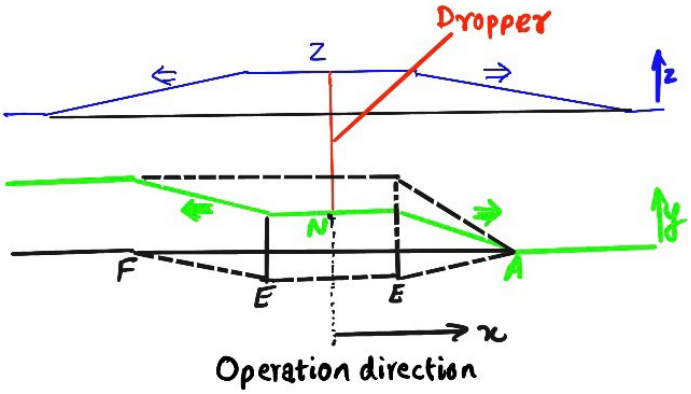



Fig 10: moment after full wave passing through dropper

## 6.4 EFFECT OF DOPPLER COEFFICIENT

When a pantograph operates at high speed along a contact line, the wave generated by the pantograph and the overhead contact line vibration and the pantograph in high-speed operation together form a highly complex vibration state.

The static passive mass of the contact line or reflection of a transverse wave generated by another nonuniform part will not increase the amplitude. However, reflection generated when the primary transverse wave meets a dropper, or steady arm will increase amplitude when the pantograph is close to a transverse wave. It is assumed that the pantograph slides along the contact wire at speed v, and contact force $\Delta F_2'$ between the strip and contact wire increases under some interference. Such incremental effect of contact force will be overlapped onto another motion component of the contact wire and pantograph linearly. The corresponding motion speed is [1]:

$$y_0' = \Delta F_0'/2m_c C_p$$

This will generate a wavefront in the same direction as the operation of the pantograph. According to the Doppler effect of a moving source, the slope of such a wavefront is

$$y_0' = \frac{\dot{y}_0}{C_p - v}$$

At the next dropper point, a reflection with coefficient of less than one is generated by the wavefront. The reflection wave moves toward the pantograph at the slope of $y_r = r y_0$, and the vertical movement speed of the pantograph will be

$$\dot{y}_1 = y_r'.(C_p + v) = \dot{y}_0.r.\frac{C_p + v}{C_p - v}$$

The reflection wave meets the pantograph, which is like a moving receiver, so its coefficient (Cp + v) is received by such a moving receiver. This causes a saltatory rise of the pantograph and overhead contact line contact force.

$$\Delta F_1' = 2m_c C_p.\dot{y}_1 = \Delta F_0'.\frac{r}{\alpha} \ldots\ldots\ldots \text{Eq10}$$

where $\alpha = \frac{C_p - v}{C_p + v}$, called the Doppler coefficient of dynamic interaction between the pantograph and the contact line.

## 6.5 AMPLIFICATION COEFFICIENT

It can be seen from Eq 10 that propagation and reflection of a wave along the contact wire lead to a change of the pantograph and overhead contact line contact force. The ratio of two adjacent contact force increments is r/α, which is called the amplitude coefficient and is usually expressed with γ, namely γ=r/α If γ > 1, increments of pantograph and overhead contact line contact force $\Delta F_1'$ will be larger than the original increment, $\Delta F_0'$

Fig. 11 shows a simple example of interaction between pantograph and contact line when the amplitude coefficient is different.

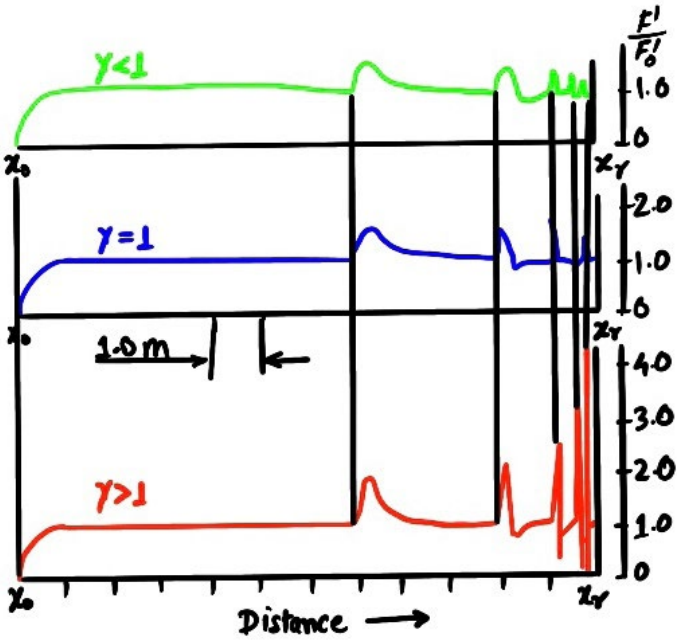



Fig 11: Effect of Amplification Coefficient

The contact wire is discontinuous at point $x_r$. The pantograph with mass $M_p$ slides to the discontinuous point at speed v, coming into contact with the contact wire but not applying any force to it. A force $F_0'$ appears suddenly after it passes point $x_0$, uplifting the contact wire from such point. Such uplift is propagated forward at fluctuation propagation speed $C_p$, and is reflected at the discontinuous point. The wavefront reflected is propagated toward the pantograph and reflected at the pantograph. Meanwhile, the motion of the pantograph brings increased energy to the contact wire. This process repeats again and again until the pantograph reaches $x_r$.

It can be seen from Fig. 11 that, if γ > 1, the increase of each continuous force is larger than the initial force, and system amplitude constantly increases before the pantograph reaches . In contrast, if γ < 1, the change of continuous force will be weakened, and the vibration of the contact wire will be relaxed slowly. When γ = 1, the amplitude will neither increase nor decrease, and contact force will remain unchanged.

The Doppler coefficient α is the function of operating speed v. If operating speed at γ = 1 is defined as limit speed $v_\alpha$, then when v is lower than , the amplitude of continuous force will not increase significantly. It can be derived that

$$\gamma \le 1 \Rightarrow \frac{r(C_p + v_a)}{(C_p - v_a)} \le 1 \Rightarrow v_a \le C_p . \frac{1-r}{1+r}$$

Because $r = \frac{\sqrt{T_m m_m}}{\sqrt{T_m m_m} + \sqrt{T_c m_c}}$, then

$$v_a \le \frac{C_p}{1 + 2\sqrt{\frac{T_m m_m}{T_c m_c}}} \quad \text{..... Eq 11}$$

We have already seen that $v_{max} \le \beta C_p$.However, the design speed should also be greater than the above limit. i.e., $v_{design} \ge v_\alpha$.To improve limit speed $v_\alpha$, the mass per unit length and tension of the respective contact wire and messenger wire will be selected. This equation also proves the earlier prediction that in order to increase the speed of operation, the tension of contact wire, Tc needs to be increased. When selecting parameters of the contact wire, the following condition will be met

$$C_p^2 \le \frac{T_c}{m_c}$$

The point $x_r$ in Fig. 11 is a discontinuous point. The incident wave is fully reflected. However, in actual application, this condition is avoided by the contact line. The amplification coefficient can be larger; that is, the design speed can be larger than the limit speed [1].

Example: For the contact line of NDLS-HWH line of Indian Railways, the wire combination of 65/107 sq. mm Cd-Cu/HDGC and tension combination of 1/1 kN are used. The calculated $C_p$ is 369.16 km/h and r is 0.441. When

amplification coefficient γ = 1, limit speed = 142.609 km/h, far less than the design speed of 180 km/h. If v = 180 km/h, α = 0.344, and γ = 1.280 as calculated [4].

## 6.6 NATURAL FREQUENCY OF CATENARY SUSPENSION

When vertical vibration is applied to the contact line close to the middle of a span, the frequency of vibration per second is different, and so is the exciting force. The number of frequencies within 1 second is also called vibration frequency, in units of Hz [1].

To make the contact line vibrate once within 5 seconds, massive external exciting force may be required; if vibration frequency is increased to around 1 Hz, vibration at large amplitude can be obtained using only a very small force; to improve frequency further, larger external exciting force will be necessary.

If a large amplitude can be obtained using only a very small force when at a certain vibration frequency, then such frequency is called the inherent (or natural) frequency of the contact line. As described earlier, when applying vibration to the middle of the span of a contact line at the frequency of 1 Hz, the vibration shape of the contact line will be like the one shown in Fig. 12. It can be seen that vibration does not occur at the registration point, and maximum amplitude is generated at the middle of the span; when a part of the contact line moves upward, its surrounding parts will move downward.

Catenary suspension is a vibration system with multiple degrees of freedom. It has a large amount of natural frequency. For catenary suspension consisting of equivalent span lengths, there are symmetric and antisymmetric vibration forms. In the first case, every two mass points of contact wire in mirror positions vibrate at the same phase. In the latter case, they vibrate at an inverse phase. For symmetric vibration, the antinode of vibration (the point with maximum amplitude) is located on the axis of symmetry; for antisymmetric vibration, the wave node (point with amplitude of 0) is located on the axis of symmetry; for a catenary suspension with an even number of spans, the axis of symmetry is at the suspension point [1].

For antisymmetric vibration, the length of the fundamental wave is twice the span length. If vibration is considered as a standstill wave, then its natural frequency will be

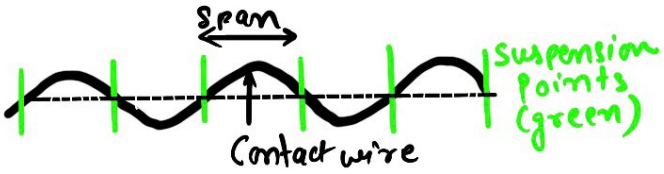



Fig 12

$f_1 = \frac{\overline{C}}{2l} = \frac{\sqrt{\frac{T_m+T_c}{m_m+m_c}}}{2l}$, where C is the average wave propagation speed of catenary suspension.

For symmetric vibration, the section of the first dropper will be considered. Its natural frequency is

$f_2 = \frac{\overline{C}}{2l+l_1} = \frac{\sqrt{\frac{T_m+T_c}{m_m+m_c}}}{2l+l_1}$, , where $l1$ is the distance between two droppers nearest to the registration point. For such simplification mode, the frequency of the first harmonic is twice the natural frequency. Other frequencies will be decided depending on their respective vibration forms.

## 7. DYNAMIC PROPERTIES OF CONTACT WIRE

Based on the discussions above, the following dynamic properties of the OHE system may be concluded:

1. Fluctuation Propagation Constant, $C_p = \sqrt{\frac{T}{m}}$ where T= tension and m = mass per unit length.

2. Doppler Coefficient, $\alpha = \frac{C_p - v}{C_p + v}$, where v is the velocity of operation of the train.

3. Reflection coefficient, $r = -\frac{y_r}{y_0} = \frac{m_m C_m}{m_m C_m + m_c C_c} = \frac{\sqrt{T_m m_m}}{\sqrt{T_m m_m} + \sqrt{T_c m_c}} = -\frac{\mu\omega(j+\mu\omega)}{(1+\mu^2\omega^2)}$ , where $\mu = M/(2mCp)$

4. Amplification Coefficient, $\gamma = \frac{r}{\alpha} = \frac{r(C_p+v_a)}{(C_p-v_a)}$

5. Limiting speed, $v_a = \frac{C_p}{1+2\sqrt{\frac{T_m m_m}{T_c m_c}}}$.

6. Natural frequency in case of asymmetric vibrations, $f_1 = \frac{\bar{C}}{2l} = \frac{\sqrt{\frac{T_m+T_c}{m_m+m_c}}}{2l}$, where C is the average wave propagation speed of catenary suspension.

7. Natural frequency in case of symmetrical vibrations, $f_2 = \frac{\bar{C}}{2l+l_1} = \frac{\sqrt{\frac{T_m+T_c}{m_m+m_c}}}{2l+l_1}$, where $l_1$ is the distance between two droppers nearest to the registration point.

8. Condition for dropper not slacking: $2m_c C_c \dot{y}_0 \geq \frac{m_c g l}{r}$.

So, for designing an OHE system, these dynamic properties need to be kept in mind.

The Doppler coefficient and amplification coefficient are functions of the operating speed of an electric train, as shown in Fig. 13. When the train operating speed is close to the fluctuation propagation speed of the contact wire, the amplification coefficient will approach infinity, and the contact wire will have significant deflection. Thus, a train cannot run at speed close to the fluctuation propagation speed.

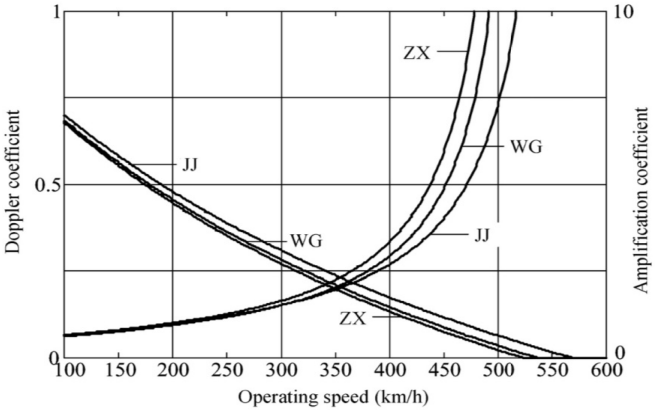



Fig 13: Relation between doppler coefficient, Amplification factor and

## 8. EXAMPLE OF PARAMETERS IN INDIAN RAILWAYS

The Railway Board had issued guidelines for running trains at 160 kmph in Delhi- Mumbai and Delhi - Howrah sections [5]. Of the many proposed changes, the changes related to Pantodynamics is being discussed here. To increase the operational speed of OHE to 160 kmph, the static and dynamic parameters of the OHE needs to be improved [4]. For this purpose, the following options are being considered.

### 8.1 OPTION 1: TENSION IN OHE INCREASED TO 1100+1100KGF

Tension in regulated OHE shall be increased in 65sq. mm Cd-Cu catenary wire and 107 sq. mm HDGC contact wire from 1000 kgf to 1100 kgf. The table below gives a comparison of the static and dynamic parameters of the existing 1000/1000 kgf tension and proposed OHE with this option of 1100+1100 kgf tension as tabulated below [4]

| OHE Configuration | Symbol | Unit | 65/107 Existing | 65/107 Proposed |
|---|---|---|---|---|
| Cross-section of contact wire | $w_c$ | $mm^2$ | 107 | 107 |
| Cross-section of catenary wire | $w_m$ | $mm^2$ | 65 | 65 |
| Tensile force of contact wire | $T_c$ | Kgf | 1000 | 1100 |
| Tensile force of catenary wire | $T_m$ | Kgf | 1000 | 1100 |
| Mass per unit length of contact wire | $m_c$ | Kg/m | 0.951 | 0.951 |
| Mass per unit length of catenary wire | $m_m$ | Kg/m | 0.60 | 0.60 |
| Design train speed | $v_{max}$ | Km/h | 180 | 180 |
| Span length | l | m | 72 | 72 |
| Elasticity at mid span | $e_{mid} = \frac{l \times 1000}{4 \times (T_m + T_c) \times 9.8}$ | mm/N | 0.92 | 0.82 |

| OHE Configuration | Symbol | Unit | 65/107 Existing | 65/107 Proposed |
|---|---|---|---|---|
| Fluctuation propagation constant | $C_p = \sqrt{\frac{(T_c) \times 9.8}{m_c}} \times 18/5$ | Km/h | 369.16 | 387 |
| 70% of fluctuation propagation constant | $0.7 \times C_p$ | Km/h | 258 | 271 |
| Doppler coefficient | $\alpha = \frac{C_p - v_{max}}{C_p + v_{max}}$ | - | 0.34 | 0.36 |
| Reflection coefficient | $r = \frac{\sqrt{T_m m_m}}{\sqrt{T_m m_m} + \sqrt{T_c m_c}}$ | - | 0.441 | 0.442 |
| Amplification coefficient | $\gamma = r/\alpha$ | - | 1.30 | 1.21 |
| Pushup | p | mm | 156 | 142 |
| Condemning diameter of contact wire | $d_c$ | mm | 8.25(factor of safety 2.7) | 8.25(factor of safety 2.45) |

All the parameters displayed above are in concurrence with the topics discussed.'

i. An increase in tension will increase the fluctuation propagation constant, ultimately increasing the speed of operation.

ii. Also, all the other physical dimensions remain the same, so the mass per unit length is the same.

iii. The elasticity at the mid-span of the contact wire is reduced as the tension is increased. Ideally, if the elasticity is identical throughout the span, there shall be no problems. It is desirable that at supports and mid-span, the elasticity should be same to minimize the vibrations.

iv. Doppler coefficient, $\alpha = \frac{C_p - v_{max}}{C_p + v_{max}} = \frac{2C_p}{C_p + v_{max}} - 1 = \frac{2}{1 + \frac{v_{max}}{C_p}} - 1$ which means the doppler coefficient is directly proportional to the fluctuation propagation constant and hence is increased.

v. Reflection coefficient, $r = \frac{\sqrt{T_m m_m}}{\sqrt{T_m m_m} + \sqrt{T_c m_c}} = \frac{1}{1 + \sqrt{\frac{T_c m_c}{T_m m_m}}}$. Since the ratio of contact wire tension and catenary wire tension is identical, there is almost no effect on the reflection coefficient.

vi. Increased doppler coefficient results in decreased amplification factor, which is desirable for the system, as explained earlier.

vii. Increased tension will obviously reduce the pushup value since the elasticity is reduced, which means that more force is required for uplifting the contact wire with the same amount as that of the earlier case.

The condemning diameter is kept the same, but the factor of safety is reduced since the same cross-section is being used to handle larger tension. The ratio between breaking load and adopted tension is termed as factor of safety, which should be more than 2.3 for the safe operation of trains.

The advantage of this scheme is that static and dynamic parameters of OHE will improve marginally, keeping the condemning diameter same as before. So, most of the existing OHE structure need not be modified to a great extent.

## 8.2 OPTION II: TENSION IN OHE INCREASED TO 1200+1200 KGF

Tension in regulated OHE shall be increased in 65sq. mm Cd-Cu catenary wire and 107 sq. mm HDGC contact wire from 1000 kgf to 1100 kgf. The table below gives a comparison of the static and dynamic parameters of the existing 1000/1000 kgf tension and proposed OHE with this option of 1200+1200 kgf tension as tabulated below [4]:

| OHE Configuration | Symbol | Unit | 65/107 Existing | 65/107 Proposed |
|---|---|---|---|---|
| Cross-section of contact wire | $w_c$ | $mm^2$ | 107 | 107 |
| Cross-section of catenary wire | $w_m$ | $mm^2$ | 65 | 65 |
| Tensile force of contact wire | $T_c$ | Kgf | 1000 | 1200 |
| Tensile force of catenary wire | $T_m$ | Kgf | 1000 | 1200 |
| Mass per unit length of contact wire | $m_c$ | Kg/m | 0.951 | 0.951 |
| Mass per unit length of catenary wire | $m_m$ | Kg/m | 0.60 | 0.60 |
| Design train speed | $v_{max}$ | Km/h | 180 | 180 |
| Span length | l | m | 72 | 67.5 |
| Elasticity at mid span | $e_{mid} = \frac{l \times 1000}{4 \times (T_m + T_c) \times 9.8}$ | mm/N | 0.92 | 0.72 |
| Fluctuation propagation constant | $C_p = \sqrt{\frac{(T_c) \times 9.8}{m_c}} \times 18/5$ | Km/h | 369.16 | 404.39 |
| 70% of fluctuation propagation constant | $0.7 \times C_p$ | Km/h | 258 | 282 |
| Doppler coefficient | $\alpha = \frac{C_p - v_{max}}{C_p + v_{max}}$ | - | 0.34 | 0.38 |
| Reflection coefficient | $r = \frac{\sqrt{T_m m_m}}{\sqrt{T_m m_m} + \sqrt{T_c m_c}}$ | - | 0.441 | 0.443 |
| Amplification coefficient | $\gamma = r/\alpha$ | - | 1.30 | 1.17 |
| Pushup | p | mm | 156 | 130 |
| Condemning diameter of contact wire | $d_c$ | mm | 8.25(factor of safety 2.7) | 8.42(factor of safety 2.3) |

i. The following conclusions may be drawn from the table given above:Increased tension to 1200 kgf improves the static and dynamic parameters of the contact and catenary wire to a greater extent.

ii. The span length has been decreased to justify the increased tension.

iii. The elasticity of the contact wire at the mid-span is also decreased as an obvious result of increased tension. Hence, the pushup value is also reduced since more force is required for pushing a similar amount of deflection.

iv. The fluctuation propagation constant is improved significantly, and hence, the doppler coefficient is also increased according to the relationship described in the option I section. Because of this, the speed limit of the train is improved.

v. Since the amplification coefficient is reduced, there is less chance of vibration in OHE since its amplitudes are significantly reduced.

The condemning diameter has to be changed to accommodate the increased tension while keeping the required factor of safety as 2.3. It has been found that if the same condemning diameter is kept, the factor of safety is reduced to 2.25, which goes below the required limit of 2.3

The advantage of this option is that the static and dynamic parameters of the OHE have been improved significantly, resulting in a very stable system. However, the main disadvantage of this option is that the condemning diameter of the OHE is to be changed [4].

This article shall guide officers for the understanding of various instructions issued by the Railway Board and RDSO regarding speed up-gradation of IR to 160kmph.

## 8.3 COMPARISON OF PARAMETERS WITH OTHER RAILWAYS[1]

| OHE Configuration | Symbol | Unit | 65/107 Existing on IR | 65/107 proposed Option II in IR | WG High-speed Railways | ZX High-Speed Railway | Beijing Tianjin Intercity Railway |
|---|---|---|---|---|---|---|---|
| Tensile force of contact wire | $T_c$ | Kgf | 1000 | 1200 | 3000 | 2850 | 2700 |
| Tensile force of catenary wire | $T_m$ | Kgf | 1000 | 1200 | 2100 | 2300 | 2100 |
| Mass per unit length of contact wire | $m_c$ | Kg/m | 0.951 | 0.951 | 1.350 | 1.350 | 1.082 |
| Mass per unit length of catenary wire | $m_m$ | Kg/m | 0.60 | 0.60 | 1.065 | 1.065 | 1.065 |
| Design train speed | $v_{max}$ | Km/h | 180 | 180 | 350 | 350 | 350 |
| Span length | l | m | 72 | 67.5 | 48 | 48 | 48 |
| Elasticity | $e_{mid} = \frac{l \times 1000}{4 \times (T_m + T_c) \times 9.8}$ | mm/N | $e_{mid}$= 0.92 | $e_{mid}$= 0.72 | $e_{max}$=0.3004 $e_{min}$=0.2434 | $e_{max}$= 0.3049 $e_{min}$= 0.2473 | $e_{max}$= 0.2967 $e_{min}$= 0.1319 |
| Fluctuation propagation constant | $C_p = \sqrt{\frac{(T_c) \times 9.8}{m_c}} \times 18/5$ | Km/h | 369.16 | 404.39 | 536.7 | 523.1 | 568.7 |
| 70% of fluctuation propagation constant | $0.7 \times C_p$ | Km/h | 258 | 282 | 375.69 | 366.17 | 398.09 |

| OHE Configuration | Symbol | Unit | 65/107 Existing on IR | 65/107 proposed Option II in IR | WG High-speed Railways | ZX High-Speed Railway | Beijing Tianjin Intercity Railway |
|---|---|---|---|---|---|---|---|
| Doppler coefficient | $\alpha = \frac{C_p - v_{max}}{C_p + v_{max}}$ | - | 0.34 | 0.38 | 0.210 | 0.198 | 0.237 |
| Reflection coefficient | $r = \frac{\sqrt{T_m m_m}}{\sqrt{T_m m_m} + \sqrt{T_c m_c}}$ | - | 0.441 | 0.443 | 0.426 | 0.444 | 0.467 |
| Amplification coefficient | $\gamma = r/\alpha$ | - | 1.30 | 1.17 | 2.029 | 2.242 | 1.970 |

## 9. ANNEXURE

### 9.1 DERIVATION OF TOTAL RESPONSE

$$\frac{\delta^2 y}{\delta t^2} = C_p^2 . \frac{\delta^2 y}{\delta x^2} + \frac{F_0'}{m}\delta(x - vt)dx$$

If the collector strip is located at point x=0 at the time t =0, its location at time t is given by $x_t = v_t$ . The delta function can be replaced by a Fourier series where this relation of $x_t$ can be used as a boundary condition.

$\delta(x - x_t) = \sum_{n=1}^{\infty} C_n . sin\left(\frac{n\pi x}{l}\right)$, , where l is the length of the section considered and $C_n = \frac{2}{l} . sin\left(\frac{n\pi x_t}{l}\right) = \frac{2}{l} . sin\left(\frac{n\pi vt}{l}\right)$.

Substituting this in differential equation,

$$\frac{\delta^2 y}{\delta t^2} = C_p^2 . \frac{\delta^2 y}{\delta x^2} + \frac{2F_0'}{ml} \sum_{n=1}^{\infty} sin\left(\frac{n\pi vt}{l}\right) . sin\left(\frac{n\pi x}{l}\right)$$

As a solution of this equation the function $y(x,t) = \sum_{n=1}^{\infty} y_n(t) . sin(n\pi x/l)$ can be used. Inserting this to the differential equation,

$$\ddot{y}_n(t) + C_p^2 \left(\frac{n\pi}{l}\right)^2 y_n(t) = \frac{2F_0'}{ml} sin\left(\frac{n\pi vt}{l}\right)$$

The general solutions for the equations of this form is

$y_n(t) = C_{1n} cos(n\pi C_p t/l) + C_{2n} sin(n\pi C_p t/l) + A_n sin(n\pi vt/l)$ where,

$$A_n = \frac{2F_0' l}{m(n\pi)^2 (C_p^2 - v^2)}.$$

The coefficients $C_{1n}$ and $C_{2n}$ are deduced from boundary conditions

$y_n(0) = 0\ \dot{y}_n(0) = 0.$ Putting these in the equations, we get,

$C_{1n}=0$

$$y_n(0) = C_{2n}(n\pi C_p t/l) + A_n(n\pi vt/l) = 0$$

So, $C_{2n} = -(v/C_p) . \frac{2F_0' l}{m(n\pi)^2 (C_p^2 - v^2)}$. This results in the complete solution, i.e.

$$y(x,t) = \frac{2F_0' l}{m\pi^2 (C_p^2 - v^2)} . \sum_{n=1}^{\infty} \frac{1}{n^2} . sin\frac{n\pi x}{l} \left( sin\frac{n\pi vt}{l} - \frac{v}{C_p} sin\frac{n\pi C_p t}{l} \right)$$

## 10. SYMBOLS USED AT A GLANCE

In any symbol used, subscript 'm' is for messenger/ catenary wire, and subscript 'c' is for contact wire.

- $F_0$ = Contact force of pantograph applied to contact wire.
- $F_o$' =Force per unit length applied on the contact wire.
- $\Delta F_0$' = incremental force on the contact wire.
- $\Delta F_1$'= incremental force after the effect of wave reflection
- $F_r(t)$= Restraining force
- $F_y$= Total vertical force on the y axis
- $T$ = Tension
- $T_m, T_c$= Tension of messenger wire and contact wire
- $m$= mass per unit length
- $m_m, m_c$= = mass per unit length of messenger and contact wire.
- $C_p$ = fluctuation propagation constant
- $C_m, C_c$=fluctuation propagation constant of messenger and contact wire.
- $l$ = length of the span.
- $l_1$ = length between adjacent droppers.
- JJ=Beijing-Tianjin Railway
- WG= Wuhan Guangzhou Railway
- ZX=Zhengzhou X'ian Railway
- y,$y^{'}$ = speed of wave
- v= velocity of the pantograph.
- y,$y^{''}$ =acceleration of pantograph.
- $y_r$ =reflected wave
- $y_0^{'}$ = speed of wave as seen by pantograph
- r = reflection coefficient.
- α = Doppler coefficient
- γ = Amplification factor , $\mu=M/(2C_p m)$
- $f_1, f_2$ = natural frequencies in case of asymmetrical and symmetrical interaction

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IREEN JOURNAL

# BULLET TRAIN : AN INSIGHT INTO HIGH-SPEED ELECTRIC TRACTION



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## Abstract:

India has undertaken an ambitious project for a bullet train to run between two of the country's two major cities, Mumbai and Ahmedabad, with the help of Japan.

A high-speed rail corridor is to be constructed for this bullet train, covering a distance of 500 kms in 2 hours(approx.). There are many aspects and challenges associated with such level of installation, construction and operation.

This article discusses some of the salient features of High-speed electric traction.

## INTRODUCTION

High-speed rail (HSR) is a type of rail transport that runs significantly faster than traditional rail traffic, using an integrated system of specialized rolling stock and dedicated tracks. While there is no single standard that applies worldwide, new lines over 300 kilometres per hour (160 mph) are widely considered to be high-speed.

The Indian government has modelled a company, National High-Speed Rail Corporation Limited (NHSRCL), as 'Special Purpose Vehicle' in the joint sector with equity participation by Central Government through Ministry of Railways and two State Governments viz. Government of Gujarat and Government of Maharashtra.

NHSRCL was incorporated on 12th February 2016 under the Companies Act, 2013, to finance, construct, maintain and manage the High-Speed Rail Corridor in India.

The main challenges for high-speed electric traction are:

1. To cater to the high speeds, the MVA demand is high.

   The contact performance of Pantograph and Contact wire directly affects the current collection performance.

Some relevant features of Power supply installations and OHE addressing the above challenges for MAHSR Project (Mumbai–Ahmedabad High-Speed Rail Corridor), are discussed.

## POWER SUPPLY INSTALLATION

**Incoming method:**

It will be powered by double lines taken from the transmission network of 132/220kV.

**Feeding system:**

The feeding system will be single-phase AC, 50Hz, 2x25kV. 2×25kV system (power distribution at a higher voltage) makes it happen to deliver high power requirements.

**Substation System:**

There will be a spacing of 50 to 60km between the adjacent traction substations (TSS).

There will be a 25 to 30 km interval between TSS and the sectioning and paralleling post (SP), and there will be sub-sectioning and paralleling post (SSP) in the midway of the SP and TSS.

## TRACTION TRANSFORMER

The maximum power current of conventional lines is 600A to 700A as compared to 1000A for High-speed rails. Therefore, it is necessary to have a larger traction transformer capacity for HSR (High-Speed Rail) than for the conventional lines. The traction transformer capacity is 50MVA (2x25MVA) in Conventional lines, but 120MVA (2x60MVA) is required in HSR.

If fluctuations in the incoming voltage are significant in the traction substation, OLTC (On-load tap changer) will be used.

**Auto Transformer:**

It is necessary to increase the autotransformer (AT) capacity for the same reason as the traction transformer. For this reason, 15MVA capacity AT will be used for HSR as against 8MVA used in conventional lines.

**Connection Method of Traction Transformers:**

The connection methods of traction transformers used in different countries for HSR are the Scott connection method and the V- connection method.

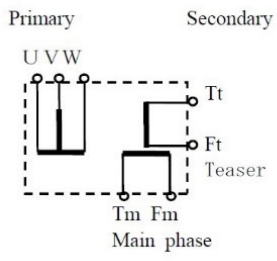



*Fig1.1: Scott connection*

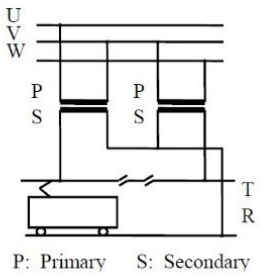



*Fig1.2: V connection*

Connection of Feeding Transformers and Operating Method:

Scott connection method is installed using two transformers, one for operation and the other for stand-by, as shown in Figure 2.1.

V-connection method is installed using three transformers, two for operation and the third for stand-by, as shown in Figure 2.2.

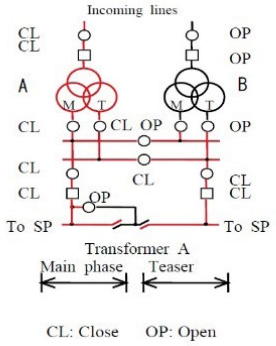



*Fig2.1: Scott connection*

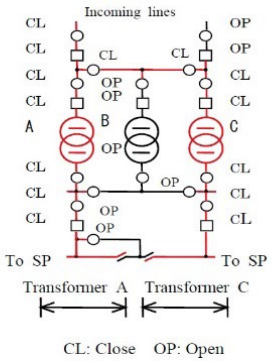



*Fig2.2: V connection*

Connection Method of Traction Transformers and Voltage Unbalance Rate:

The following formula is used for calculating the voltage unbalance rate due to the connection method of the transformers.

(a) V-connection transformer

$$u=(Es\times\sqrt{(Ia^2+Ib^2-Ia\times Ib)}/Ps)\times 100(\%)$$

(b) Scott connection transformer

$$u=(Es\times|(Im-It)|/Ps)\times 100(\%)$$

where,

u : Voltage unbalance rate (%)

Es : Line voltage (kV)

Ps : Short current apparent power (kVA)

Ia,Ib : Line current (V-connection) (A)

Im, It : Line current (Scott connection) (A)

Voltage unbalance rate calculation is done depending on the load conditions, as shown in Figure 3.1. Figure 3.2 shows the calculation result of the unbalanced rate. The voltage unbalance rate is the same in any connection when the load in one direction only. However, if there are loads in both directions, the unbalanced rate is smaller in the case of the Scott connection as compared to V-connection.

## STANDARD POWER SUPPLY NETWORK

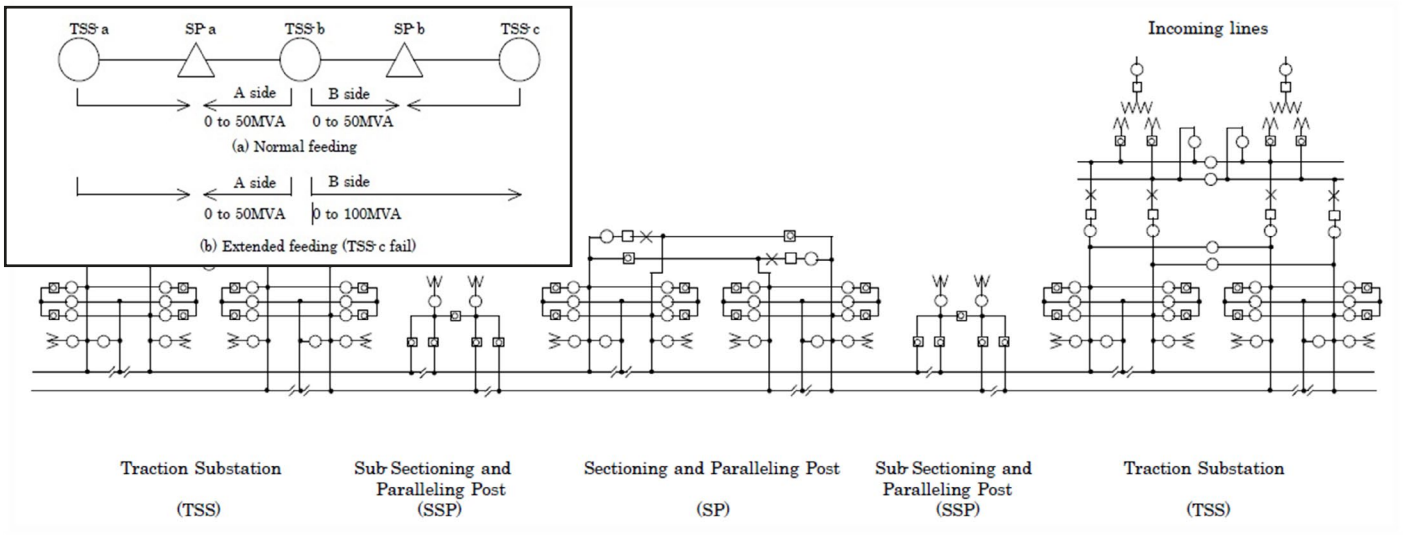



*Fig3.1: Load conditions*

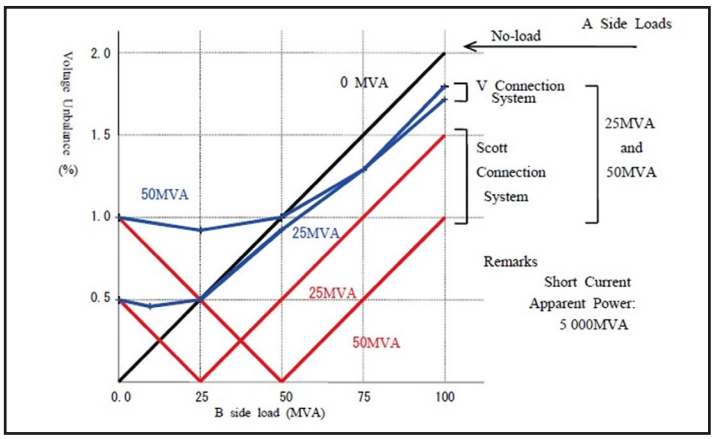



*Fig3.2: Calculation result of the voltage unbalance rate*

Connection methods adopted for high-speed rail in different countries:

| Type of method | Country |
|---|---|
| Scott connection | Japan, Taiwan, South Korea |
| V connection | France, Spain, U.K., Italy, China |

Scott connection method will be used for the following reasons:

1. The incoming circuit can be simplified.
2. The number of traction transformers is reduced.
3. The power supply voltage unbalance is reduced.

## OVERHEAD EQUIPMENT (OHE)

The pantograph must consistently maintain contact with the overhead line to supply uninterrupted, good-quality power at all times. To meet these requirements, the overhead equipment is generally designed bearing the following in mind:

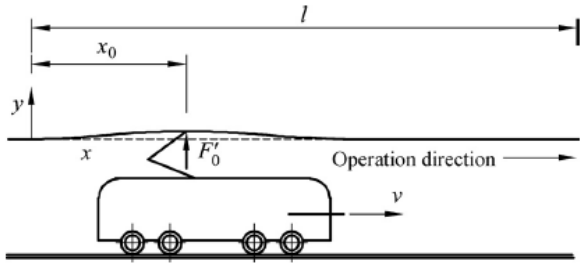
1. Must-have characteristics meeting train speed and current requirements.
2. Must be at a uniform height above the rail to optimize pantograph power collecting characteristics, so entire equipment must have uniform spring constant and bending rigidity.
3. Must have minimum vibration and motion to ensure smooth pantograph passage during high-speed operation or strong winds.
4. Must have the strength to withstand vibration, corrosion, heat, etc., while maintaining balance with reliability and operating life span.

## WAVE DYNAMICS IN PANTOGRAPH-CATENARY INTERACTION

Pantograph and Overhead contact line is a combination of inertial and elastic systems. Pantograph applies uplift force to an elastic contact line which causes offset in its initial position. The restoring force generated

from the overhead contact line pushes the pantograph to the initial position.

Interaction between elasticity and inertia causes vibration, propagated along the contact line to form a wave.




**Lateral wave propagation:**

The most critical constants for the mechanical performance of the overhead line are the tension and mass per unit length.

The square root of the ratio of the contact wire tension to the mass per unit length represents the velocity of the lateral wave propagating along the wire. This velocity is called the wave propagation velocity and is recognized as the critical speed.

$V(w) = \sqrt{(T/m)}$

Simulation and experiments have verified that as the train speed approaches the wave propagation velocity, the overhead line amplitude and local bending increase, making it harder to maintain contact between the pantograph and overhead line. It is estimated that the resulting performance drop becomes apparent when the train speed exceeds 70% to 80% of the propagation velocity. At this speed, loss of contact with the line increases greatly, and in extreme cases, the overhead line itself can be destroyed.

B= (train speed)/(wave propagation velocity) should be less than 0.7.

## OHE AS ADOPTED IN DIFFERENT COUNTRIES

The three types and characteristics of overhead equipment used for high-speed rails in different countries are shown in Figures

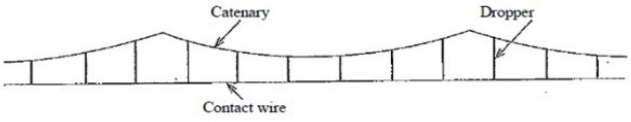



Figure 1 Simple Catenary System

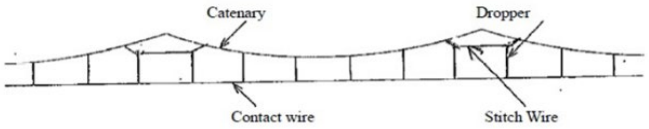



Figure 2 Simple Catenary with Stitch Wire System

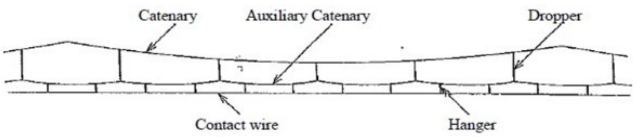
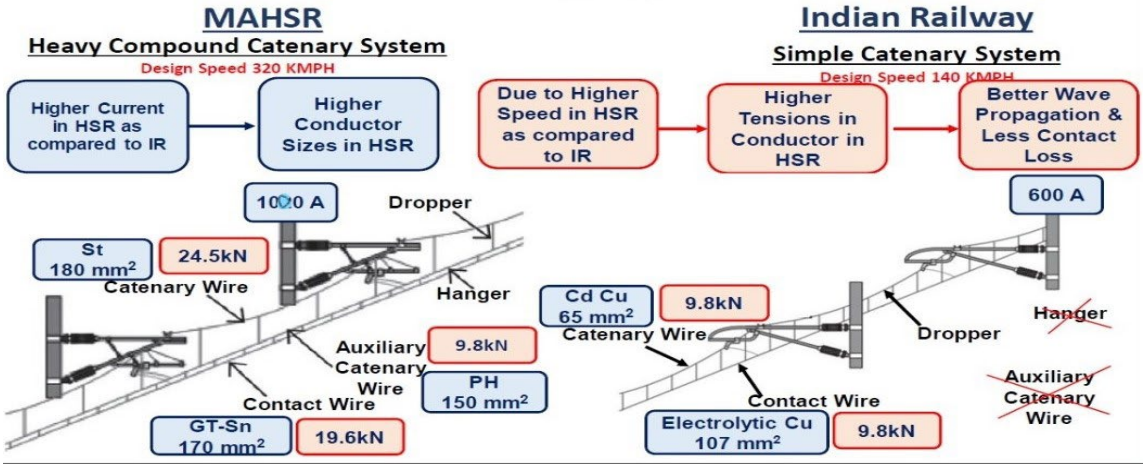



Figure 3 Compound Catenary System

(a) Simple Catenary- Japan, France, U.K., Italy, China, South Korea

(b) Simple Catenary with stitch wire- France, Spain, Germany, China

(c) Compound Catenary- Japan, Taiwan

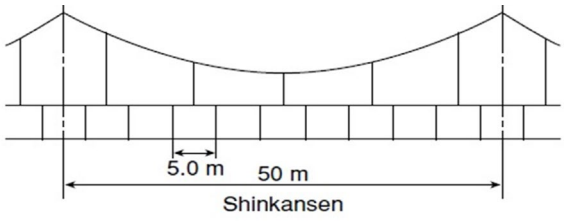


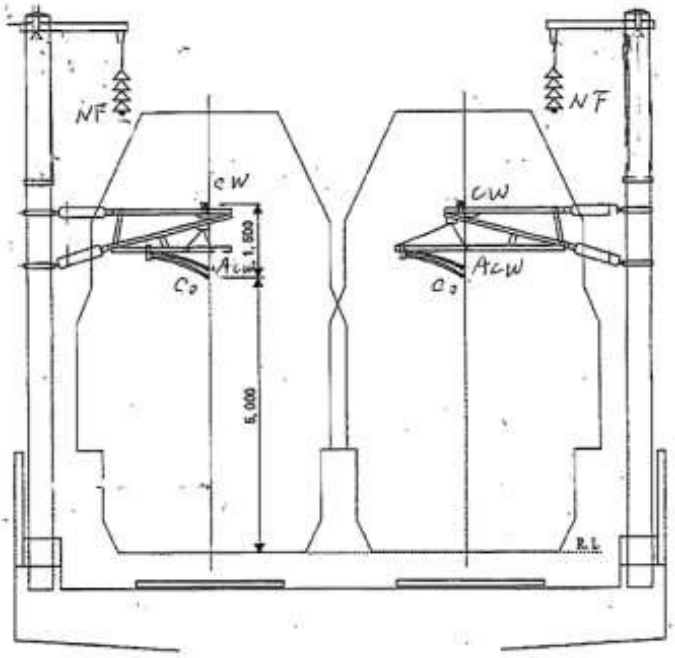
The heavy compound catenary with a higher current carrying capacity (1000 A) is proposed so as to deliver high power requirements.

The use of a heavy compound catenary with higher tension is to obtain a near-flat profile of contact wire with the help of an auxiliary catenary wire holding the contact wire with the help of 'hangers' at intervals of 5m for better current collection.

## OVERHEAD CATENARY SYSTEM COMPARISON

## STANDARD ARRANGEMENT OF OHE




Distance of contact wire (Co) and catenary wire (Cw) at bracket is 1500mm. The distance of contact wire (Co) and auxiliary wire (Acw) is 150mm. The distance between droppers is 10m.

| | |
|---|---|
| Overhead Equipment | Compound Catenary |
| Catenary wire | Galvanizing steel<br>180mm$^2$ 24.5kN |
| Auxiliary catenary wire or stitch wire | Hard-Drawn copper<br>150mm$^2$ 9.8kN |
| Contact wire | Bronze<br>170mm$^2$ 19.6kN |
| Negative Feeder (AT Feeder) | Hard-drawn Aluminium<br>300mm$^2$ 3.9kN |

## Automatic tensioning device (ATD)

An automatic tensioning device (ATD) is used to maintain constant tension automatically and thus maintain good performance for the current collection. Two options are available as follows:

(a) Pulley Type:



(b) Spring type:



Advantages of Spring type ATD type are:

- In this method, there is no need to apply oil to the cable.
- Wire breakage due to ageing of the cable problem resolved.
- It is compact as compared to the pulley type.
- Lighter than the 1500kg of pulley type.

Currently, conversion from pulley type to spring type is being promoted in Japan's Shinkansen. After confirming the weather conditions of the project area, the spring type is proposed for adoption.

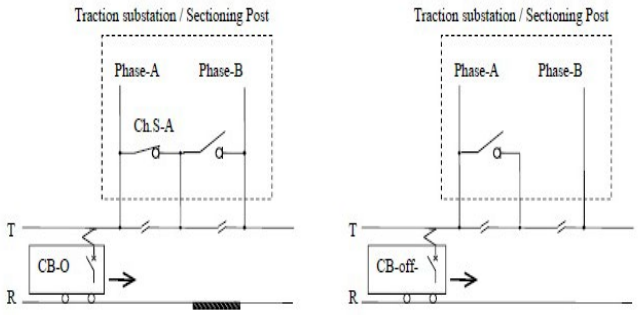
## Neutral Section

Neutral sections (NS) are of two types:

(a) Power supply installation (PSI) side switching method

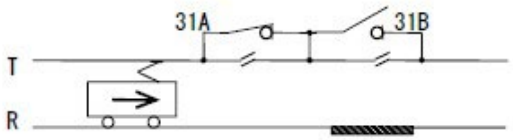
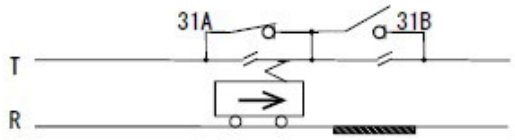
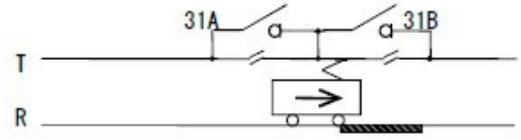
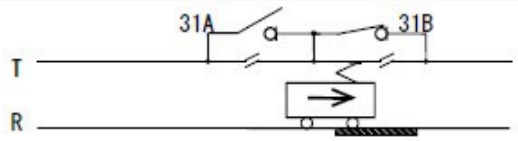
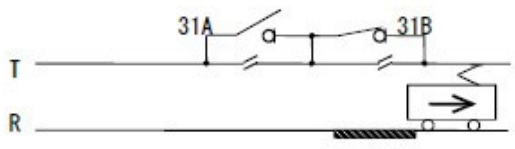
(b) On-board circuit breaker (CB) off method

They are shown below figures:




Ch.S : Changeover switch CB : Circuit breaker T : Catenary R : Rails

## Power supply installation (PSI) side

| Item | | Operation of the train and switches |
|---|---|---|
| (a) | Passing train is before the section-A |   |
| (b) | Train passed the section-A |   |
| (c) | Track circuit detected the train (Switch-A off) |   |
| (d) | On switch-B after switch-A Off |   |
| (e) | Train passed the track circuit |   |
| (f) | Go back the state (a) | |

## switching method

(The changeover section system)

The main devices are the track circuit, switch-A, switch-B, section-A, and section-B. The figure

Illustrates the down direction for switch-A is normally on mode, switch-B is normally off mode.

The power outage time is about 0.3 seconds.

## CONCLUSION

The first high-speed rail of India will bring a plethora of benefits such as transforming infrastructure, reducing traffic, and generating employment. High-speed rail will also bring technology advancements in many fields, including electric traction, which will benefit the country's railway system.

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IRIEEN JOURNAL

# CB TRIPPINGS: ANALYSIS AND AVOIDANCE



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## 1.0 Scope of this article

This article stipulates the action to be taken for monitoring & analysis of feeder CBs tripping and suggests relevant checkpoints for system improvements for OHE power without interruptions for long.

## 2.0 Background

In conventional 25 kV ac traction systems, two feeder circuit breakers feed the traction power to the OHE on both sides of the TSS. As per the tripping data analyzed over the years, it is learnt that maximum numbers of faults occur on OHE only. With the continuous increase in the number of trains at any time in the feeding zone due to increased traffic density and automatic signalling, even a slight interruption of traction supply results in several trains losing punctuality. The signal getting blank is also observed if the signalling department does not provide IPS (Integrated Power Supply). Therefore, it is essential to analyze the feeder CB tripping as a preventive and corrective action to ensure better reliability of OHE (traction power).

CB tripping in feeding supply to OHE is taken very casually though it has many repercussions; some are very serious. CB trippings are not analyzed to its conclusion since the majority remains unexplained. This has lead to a situation where minimal effort is made to control trippings. However, CB tripping is a very fair indication of the health of Of CB. The target of 5 trippings/CB/month should be the aim of maintaining engineer. The healthiness and safe operation of OHE is generally known by the number of CB trippings of that section, whether they are of known/ transient type.

The in-depth analysis of every CB tripping indicates the action that needs to be taken to make the system healthier.

Analysis of OHE tripping is necessary to reduce failures and ensure the safe operation of the system. Hence, tripping analysis of all the CBs should be prepared every month and identify the CBs with abnormally high or low trippings or no trippings to make an in-depth analysis regarding the reason for tripping. The main reason for such trippings of CBs is relay settings, TSS earthing, complete OHE system, clearance in OHE, birds nest, trees, etc. There is a need to identify areas/zones and accordingly action plan to reduce the CB trippings to an optimal level.

## 3.0 Analysis of faults on OHE

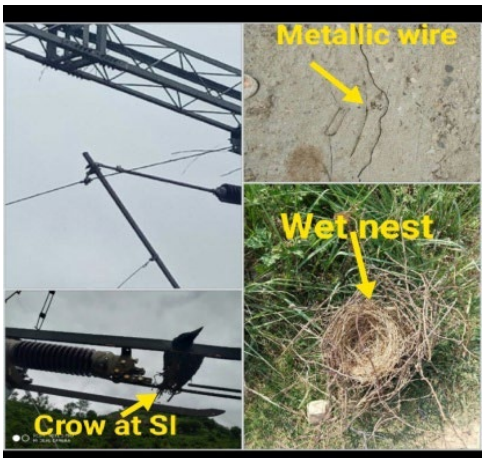
3.1 Every fault results in heavy current flow, causing stress in the overhead equipment (OHE). The damage is more in case of arcing faults wherein cutting some strands of catenary wire, pitting of contact wire and flashing/breakage of insulators shed etc. may also result.

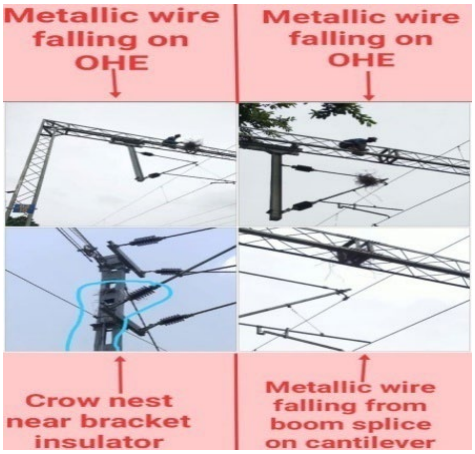
3.2 Repeated transient faults occurring at the exact location may finally result in breakage catenaries/ contact wires or insulators resulting in the permanent breakdown of OHE.

3.3 In case of permanent faults due to failure of any equipment, e.g. insulators, substation/switching equipment, lightning arresters and OHE breakdowns etc., feeder CB trips. The single-shot auto re-closer automatically closes the CB after nearly 500 ms, and it trips again, and the relay locks out. It is easier to locate such faults, as in most of the cases, the damage is visible.

3.4 Traction Power controllers reclose the CB with different combinations of system configurations so as to identify and localize the faulty section.

3.5 It is observed that for many trippings, CB holds after reclosing. Likely reasons of transient trippin attributed by Railways are tabulated as under:

| Sr. No. | Likely reasons for transient tripping | Remarks/Remedial measures | Related Photo/Pic/Matter. |
|---|---|---|---|
| 1 | Suspected bird/ crow/ monkey/ snake faults | RDSO has issued a drawing of the anti-climbing arrangement of OHE mast vide RDSO letter no. TI/OHE/ INS/GEN/08 dated 03.11.2008, which should be adopted to reduce such menace. Strict compliance to Maintenance Instruction no. TI/MI/0050 on "Prevention from Bird Menace on Traction Installations (OHE/PSI)". | For anti-climbing on sensitive OHE parts<br><br>For anti-bird measures. |
| 1A | 1. Crow carrying metallic wire and dropping on OHE: Leads to OHE trippings.<br>2. Crow carrying wet materials and dropping on OHE: Leads to OHE trippings.<br>Bridging of a portion of OHE at different potentials as in section insulator assembly. : OHE damages / OHE trippings. | |  |
| 1B | Bridging live and dead portion of AT arcing horns: This causes do barrel down and no O/P.<br><br>Sitting of crows and touching beaks while one at dead a portion of OHE and on the charged side on<br>cantilevers: Flashing / petticoats breakage/ breakage of cantilever consequently entanglement of pantograph. | |  |

| Sr. No. | Likely reasons for transient tripping | Remarks/Remedial measures | Related Photo/Pic/Matter. |
|---|---|---|---|
| 1C | Falling of metallic wire from the nest and touching OHE: Falling metallic wire from the boom of portals causes OHE trippings/failures.<br>Touching of wet sticks/straws. etc the from the nest and touching OHE:It causes OHE trippings. | |  |
| 1D | Fighting of birds/ Crows near dead and live OHE: This leads to OHE breakdown short-circuiting and sometimes unnecessary OHE trippings.<br>Hovering of crows for its prey/food etc. in the vicinity of OHE: Leads to OHE breakdown due to short circuiting between the live and dead portion of OHE. | |  |
| 1E | Snake fault | Quick feet are patrolling/foot plating to identify the affected section of OHE as per FD (Fault distance) indicated by the associated CB. Removing the snake by operating a rod or so. | <br>Snake Hanging from BT Insulator |

| Sr. No. | Likely reasons for transient tripping | Remarks/Remedial measures | Related Photo/Pic/Matter. |
|---|---|---|---|
| 1F | Monkey Fault | Quick foot patrolling/foot plating to identify affected section of OHE as per FD (Fault distance) indicated by the associated CB. Restoring OHE quickly as possible if OHE is damaged. |  Monkey Fault |

| Sr. No. | Likely reasons for transient tripping | Remarks/Remedial measures | Related Photo/Pic/Matter. |
|---|---|---|---|
| 2 | Overloading on TSS (feed extension or low incoming Voltage) | 1. Record loading data at TSS. Refer to RDSO instruction TI/IN/0019 (09/09).<br>2. Analyze voltage profile, whether Voltage is falling below the minimum permissible limit.<br>3. Long term planning of feeding zone rationalization.<br>Consider options of ONAF, higher capacity & parallel operation of transformers. |  |
| 3 | Tree touching OHE or other live parts | 1. There are instructions for tree trimming before the onset of the monsoon. No tree branch should be within 4 m of range of OHE in any case. That is trimming to be done by TRD staff.<br>2. Bigger trees should be got cut prior to the onset of monsoon, which is are likely to fall on OHE during rains with the help of Engg. Dept. |  Catenary damaged |

| Sr. No. | Likely reasons for transient tripping | Remarks/Remedial measures | Related Photo/Pic/Matter. |
|---|---|---|---|
| 4 | Flash overs on insulators tracking bad weather/ extreme pollution conditions | The minimum creepage distance of insulators has been increased from 840 mm to 1050 mm.<br>1. Ensure that insulators of correct type & creepage distance are provided based on the pollution level (calculation of ESDD) as per the policy directives issued from Rly. Bd./RDSO from time to time.<br>2. All types of insulators of OHE ( Stay, Bracket, 9 ton, Post insulator and operating insulator of is the later, Core Insulator of section insulator assembly and that of PSI should be cleaned before the onset of monsoon. Also, petticoat broken insulators/ flashed insulators must be replaced. |  |
| 5 | Faults on the roof or HT side equipment of loco | 1. Feeder CB tripping time with modern numerical relays is 100-110 ms (*30-40 ms for relay+ 60 ms for CB+ 10ms for MTR*).<br>2. The loco CB time (for both DJ and VCB types) is nearly the same or more than this; therefore, even in case of a fault in Loco HT equipment like a transformer, bushing etc. TSS CB tripping may occur.<br>3. Tripping due to loco should be dealt with as per Para 20521 of ACTM Vol-II Part-,I, and close interaction of TPC with TLC should be ensured. |  |
| 6 | Fault created by foreign materials like small wires, flexible wires, etc. | Provision of standard jalis (nets) and boards on ROB & FOB, apart from maintenance precautions taken at the time of birds nesting periods, can reduce the problem. |  |

## Some Affected Assets of TRD due to faults.

| Sr. No. | TRD Assets | Effect on asset | Related Photo/Pic/Matter. |
|---|---|---|---|
| 1 | Post insulator: | It gets flashed, or sometimes petticoats get broken. |  |
| | Stay Insulator: | It gets flashed, or sometimes petticoats get broken. | |
| | Bracket Insulator: | It gets flashed, or sometimes petticoats get broken. | |
| 2 | Sectioning insulator (Core insulator) of SI assembly: | Core insulator gets damaged; SI gets damaged badly, sometimes. |  |
| | AT (Auxiliary Transformer): | No supply to the station, LC gates or other installation. | |
| | Catenary wire under the boom of portals/TTC: | Catenary wire strands get stranded or catenary wire parts, sometimes. | |
| 3 | Isolator Switch: | Tripping of OHE or no supply to further section due to jumper/ post insulator breakage. |  |
| | Catenary wire under FOB/ROB (Foot over bridge/ Road over the bridge): | The catenary wire gets damaged. | |

| Sr. No. | TRD Assets | Effect on asset | Related Photo/Pic/Matter. |
|---|---|---|---|
| 4 | Other locations where multiple cantilevers are there, and other PSI installations etc.: | Gantry locations and high towers may get affected due to crow/bird nests. |   |

## Effect of faults on Equipment/Rail Services:

| Sr. No. | Details of particulars |
|---|---|
| 1 | Flashing /petticoat breakage of Bracket Insulator of cantilever leading to panto entanglement |
| 2 | Flashing /petticoat breakage of Stay Insulator of cantilever leading to panto entanglement |
| 3 | Damage of Section insulator assembly or breakage leading to severe repercussion on traffic operation. |
| 4 | Catenary wires under ROB/FOB/Booms of portals/TTC booms leading to disruption of traffic. |
| 5 | AT (Auxiliary Transformer) failure leading to no light at stations/ Gates Telecom Huts and other services. |
| 6 | Isolator fails to lead to no supply in a sector, and appreciably long distance and more trains are disturbed. |
| 7 | The life of the switchgear & equipment reduces due to increased operation and switching surges. |
| 8 | Maintenance of the Switchgear & Equipment increases. |
| 9 | Disruption to traffic movement. |
| 10 | Train stalling on Gradient. |
| 11 | Rail scabbing on Gradient. |
| 12 | Signal aspect flowing back/becoming blank. |
| 13 | Failure of Loco due to ICDJ (Impossibility to close Dis-jointer). |
| 14 | An increased failure of Loco Auxiliary machines due to switching surges. |
| 15 | Standing Power Arc at Feeding Post Overlap in case loco panto being there. |
| 16 | Extra operation of loco breakers. |
| 17 | Extra strain on Drivers, TPCs and many more. |

3.6 There are some cases reported by Railways wherein a persistent arcing fault on Oresin in tonto severe damage to system them e.g, they are melting of insulators or ferrous fittings etc. Such incidences occur mainly due to high resistive faults, which should be analyzed in detail as elaborated in Para 5.0 below.

3.7 In the CB tripping data received from Railways, it is observed that large number of feeder CB tripping results if it is feeding to a nearby loco shed, long siding or a large yard.

| Sr. No. | Likely reasons for transient tripping | Action suggested |
|---|---|---|
| 1 | Mal operation of Isolators at loco sheds/Trip sheds/Loading sidings. | Interlocks between Isolators at Loco shed ip sheds/Freight Sheds to be provided to avert non-sequential operation by staff. |
| 2 | Loco testing. | Circuit Breakers in the feeder of loco sheds trip sheds/ Freight sheds/ yards and branch lines to be provided to identify tripping due to loco testing. |
| 3 | Dirty Loco roof insulators. | Cleaning of the roof and roof bar insulators and other insulators and equipment. |
| 4 | Reduced clearance at the panto-graph bow end | Ensuring horizontal mounting of panto to ensure required clearance |
| 5 | Loco ET-2 flashover, particularly on VCB locos | Arc horn gap of ET-2 to be increased to 90+5 mm. Though instructions are available to remove ET-2 on locos with VCB (creates more surges) and LA, some locos are still with ET-2. ‘<br>Locos with VCB should not be tested with panto in the raised condition of locos with ACB |
| 6 | Inadequate length of dead section at pit thereby provision of dis-charge rod on the floating section | Ensuring floating section at the end of the pit without discharge rod |

3.7.1 In order to reduce tripping of feeder CB’s, under these situations, some Railways have provided separate feeder circuit breakers for loco sheds/ yards at the nearest switching post, however, as no time delay (grading) is permitted in distance protection for both the feeder CB’s connected in series trip simultaneously. However, in such cases, auto re-closer function in the CB feeding the loco shed/yards should be kept off so that it remains open while the main feeder CB should reclose for identifying faults in loco sheds/yards. After confirming the cause of tripping by TPC from the loco shed/yard, the CB may be closed.

3.7.2 Other possible options for this problem may be the provision of a separate CB in the feeder line for the loco techno-economicomic considerations.

## 3.8.0 Miscellaneous cases of transient/permanent faults

## 3.8.1 On account of loco running

| Sr. No. | List for reasons of transient tripping | Action suggested is |
|---|---|---|
| 1 | Loco is passing short neutral sections without opening DJ. | 1. Counseling drivers to open DJ in time at Neutral Sections and follow the caution boards.<br>2. Use of automatic switched Neutral Sections.<br>3. Lightweight of high-speed, superhigh-speed Insulators.<br>4. Paralleling of 2-3 consecutive TSS to reduce neutral sections.<br>5. Auto reclose timing to be less than 500msec to avoid tripping of Loco circuit breaker is |
| 2 | Loco is entering into the Counselling on. | Counselling to station masters for longitudinal cross-protection during block and failures. |

| Sr. No. | List for reasons of transient tripping | Action suggested is |
|---|---|---|
| 3 | Loco entering into unwired | Provision of Unwired Turns Out Caution boards at right place. |
| 4 | Loco troubles on H.T. side. | Quick decision to report to TLC to assist and the clear section as soon as possible by taking help of assistant loco. |

### 3.8.2 On Account of Engg. Department

| Sr. No. | Likely reasons for transient tripping | Action suggested |
|---|---|---|
| 1 | Dropping of rainwater through the drain hole of FOB/ ROB. | Re-location of drain holes on FOB/ROB |
| 2 | Unsafe working by Engineering Staff and falling of foreign material on OHE used in Construction work | Counselling Engineering staff about working in Electrified territory and in Construction works |
| 3 | Improper clearance at height gauge at LC Gates. | Ensuring soundness and maintenance of height of gauge from Road level. |
| 4 | Insulator flashover due to paint dropping in bridge location. | Ensuring parapet wall of 1.83 m at ROB |

### 3.8.3 On Account of Equipment Failures:

| Sr. No. | Likely reasons for transient/ permanent tripping | Action suggested |
|---|---|---|
| 1 | Snapping of OHE wires. | Bonding return path to be made stronger by using all traction bonds required.<br>Contact wire dia. should not be less than 8.25 m in mainline and 8.00 mm in other lines lower speeds. |
| 2 | Flashover at TSS IOL. | Panto flashover protection relays TVG124 to be provided at TSS with Conventional IOLs. A high-speed section insulator may avoid damage to OHE. |
| 3 | Provision of Discharge rod for Relay testing. Mal operation of Relays at TSSs due to improper settings. | 1. Every equipment failure to be critically analyzed and an action plan to be formulated to avoid recurrence.<br>2.. Recalibration of TSS Relays duly obtaining fault level of feeder line from concerned Electricity Authorities |
| 4 | Less clearance between RC and OHE. | Proper clearance has to be ensured. |
| 5 | Less clearance between overline structures to OHE. | **1.** New Insulated Catenary to be provided under FOBs /ROBs having crucial clearances.<br>**2.** The old insulated catenary wire should be replaced by a piece of the appropriate length of contact wire under OLS with the proper passage of current at both the end pieces at ending joints using continuity jumpers of 50 cm length using PG 1041- tAt nos. At each joint. |
| 6 | Less electrical clearances. | Not to allow lesser clearance. Long time electrical clearance is, 25 cm and short time electrical clearance is 20 cm |
| 7 | Ineffective Lightning Arrestors. | Checking of LAs should be life if required defective ones should be replaced. |

| Sr. No. | Likely reasons for transient/ permanent tripping | Action suggested |
|---|---|---|
| 8 | Pollution –Saline, Cement, Coal, Dust etc. | The frequency of cleaning of insulators along with the AOH of the cantilever should be increased. |
| 9 | Improper clearance at the middle mast of 4 span overlaps. | 1. Development of Insulated bracket assembly for four-span IOL and polluted areas.<br>2. Use of bent steady arm in middle double cantilever to provide better clearance in the overlap.<br>3. The Cantilevers of different Elementary sections at the middle mast of 4 spans IOL must have minimum specified clearance. |
| 10 | Flashing of insulators. | 4. Use of Composite insulators in the vandal prone zone.<br>5. Use of high creepage insulators and development of insulators with creepage of 31mm/KV.<br>6. Application of thick layer of silicon grease at cement polluted area to utilize the absorbing quality of silicon/use of composite insulators to utilize aerofoil quality of silicon composite insulators.<br>7. Application of very fine layer of silicone grease like shoe polish at Saline polluted area to utilize the hydrophobic quality of silicone is rescheduling the insulator cleaning at LC gates, Construction sites, Ballast sidings, loading sidings, ROBs etc. |

### 3.8.4 On Account of External Reasons:

| Sr. No. | Likely reasons for transient/ permanent tripping | Action suggested |
|---|---|---|
| 1 | Unauthorized persons are coming in contact with OHE. | On receipt of information from any identified person/staff, TPC may arrange to make power supply cut off. |
| 2 | Foreign Obj arrests f are calling on OHE from FOB/ ROB. | 8. The parapet wall on ROB to be ensured of proper height as indicated in manual 1.83 m. Expanded metallic screen (Protective Screen) without gap on FOB/ROB to be provided with a provision of the opaque iron sheet just above charge OHE. |
| | Falling of Overhead conductors passing across the track. | Annual joint checking of all types of power line crossing has to be done with Railway representative with supply Authority, preferably before monsoon season. |
| 3 | Derailments/accidents. | Team of all concerned department should proceed to the affected site by quickest means of communication/transport to restore affected assets- man material, fast. |
| 4 | Falling of trees/tree branches. | 9. Intensive tree trimming to be done (Pre & Post- monsoon).<br>10. Power saws, telescopic pruners (Petrol operated as well as manually operated) of M/s. Kaiser India limited bearing a cost of Rs. 45,000/-can be used for quick trimming of tree branches. It can be taken from other companies, too, of course.<br>11. Vulnerable trees like - Gulmohar, Eucalyptus need to be identified for pollarding. |

## 4.0 Use of numerical protection relays for fault analysis

Before 2009 the protective relays developed by RDSO for 25kV feeder protection were electromagnetic/ static / microprocessor type; in these types of relays, event recording, display of current, voltage, resistance & reactance parameters of fault were either not available or not standardized, however with the development of numerical type relays as per latest specification following features have been standardized:

Capability to store a maximum of ten numbers of latest fault events with date-timing in each event comprising 45 pre and 5 five most-fault waveforms.

4.2 Facility to retrieve the following data from relay through serial communication port for analysis:

1. Peak, average and RMS value of fault current and Voltage
2. Fault clearing time
3. R-X and phase angle
4. Percentage harmonics analysis of fault current

3.2 Display of Voltage, current and R-X value of 5 latest faults with date and time on relay LCD display.

Railways should make use the above features to the maximum extent for fault analysis purposes.

## 5.0 High Impedance or High resistive faults

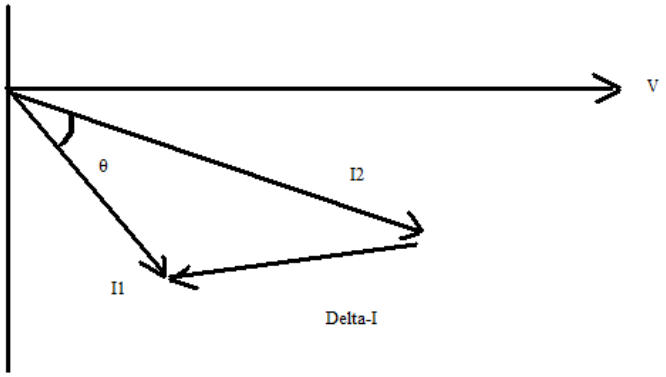
There are two characteristics of such faults on OHE, i.e. low fault currents and arcing. Arcing is the result of air gaps due to poor contact made with the ground or a grounded object.

The high impedance of the fault does not result in a substantial increase in current and, due to this, fault cannot be reliably detected & cleaning conventional protection relays like OCR & DPR.

5.1 To clear the high resistive faults, scalar Delta-I relay was developed in 1998 and subsequently, in order to increase its sensitivity, in place of scalar characteristics, Vectorial type relays were developed in 2003 as per RDSO specification no. TI/SPCPROTECTROTCT/ 1982,which should be provided by Railways.

5.2 Δ-I relay monitors the vectorial difference between base current fault current pre-defined interval generally 2-3 cycle; if the trial difference is more than the set current and other conditions are satisfied, then the relay executes the trip command. By using the Vectorial Δ-I relay, the failure of OHE due to high resistive fault may be minimized.

Vectorial delta-I relay characteristic




I1 and I2 are two consecutive current values seen by Vectorial Δ I relay

5.3 RDSO has circulated setting guidelines for ΔI relay vide letter No. TI/PSI/ PROTECT/STATIC/07 dated 23.04.2007, which should be followed. The main features of this protection relay are:

(a) It is backup protection of DPR or OCR. Its operating time is above 200 ms. In view of this, all cases her n it has operated must be carefully examined for any possibility of fault in the system or maloperation of the relay or tripping due to incorrect setting. There are cases reported by Railways wherein this relay operates along with the DPR, which means either the ΔI relay is not having the correct setting or the DPR operation might have resulted due to the culmination of high resistive fault into a solid earth fault after damage to the system or equipment.

(b) The suggested settings of Delta-I current are based on practical experiences; however, Railway s must critically review and suggest any changes if required for increasing the effectiveness of this protection.

(c) X-blinder value- This is the line reactance value monitored by the relay, and it does not trip if it is not less than the set value.

(d) There is a logic to differentiate between the sudden rise in current due to load or fault, i.e. generally load current has got high 3rd harmonics; therefore for 3rd Harmonics contents < 15% relay trips for ΔI > 2A, however for 3rd Harmonics > 15% it automatically increases set value to ΔI > 4A. Thus in this way, it analyses the 2nd and 3rd harmonics level to distinguish between load & fault currents.

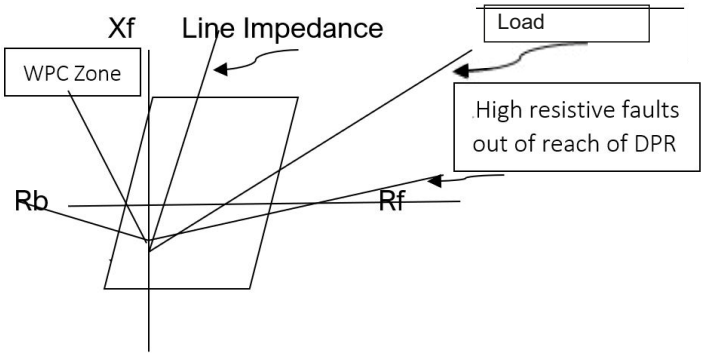
## 6.0 Important points for monitoring & analyzing faults on OHE

### 6.1 Transient faults

- Maintain the individual CB tripping detail history.
- Protection relay/element acted (DPR-{OCR, WPC, PTFF}, Panto flashover, Δ-I, IDMT etc.) should be clearly indicated for each tripping.
- If numerical type relays are provided for feeder protection, the information as mentioned in Para 4.0 above must be retrieved. For each feeder, it should be stored chronologically in soft copies with the date and location tags for analysis.
- Estimate the fault distance with the help of recorded reactance value, i.e. X considering 0.38 Ω/km reactance for single line and 0.22Ω/km for double line sections.
- Compare the Voltage, current, resistance & reactance of each tripping, if during transient tripping, similar values of reactance are observed repeatedly for the same CB, inspect the OHE surrounding the calculated fault distance (± 500 meters) and look for the flash mark on catenary and contact wire, cutting of catenary strands, flash mark/breakage on insulator shed, foreign material hanging on the catenary/ contact wire etc.

### 6.2 Additional important points for investigation of permanent faults resulting in large scale damage to OHE or traction supply system

If the relay has taken excessive time in clearing the fault or consequential damage to equipment/system is found to be substantial, then the following additional areas should also be studied to arrive at the root cause of the problem.

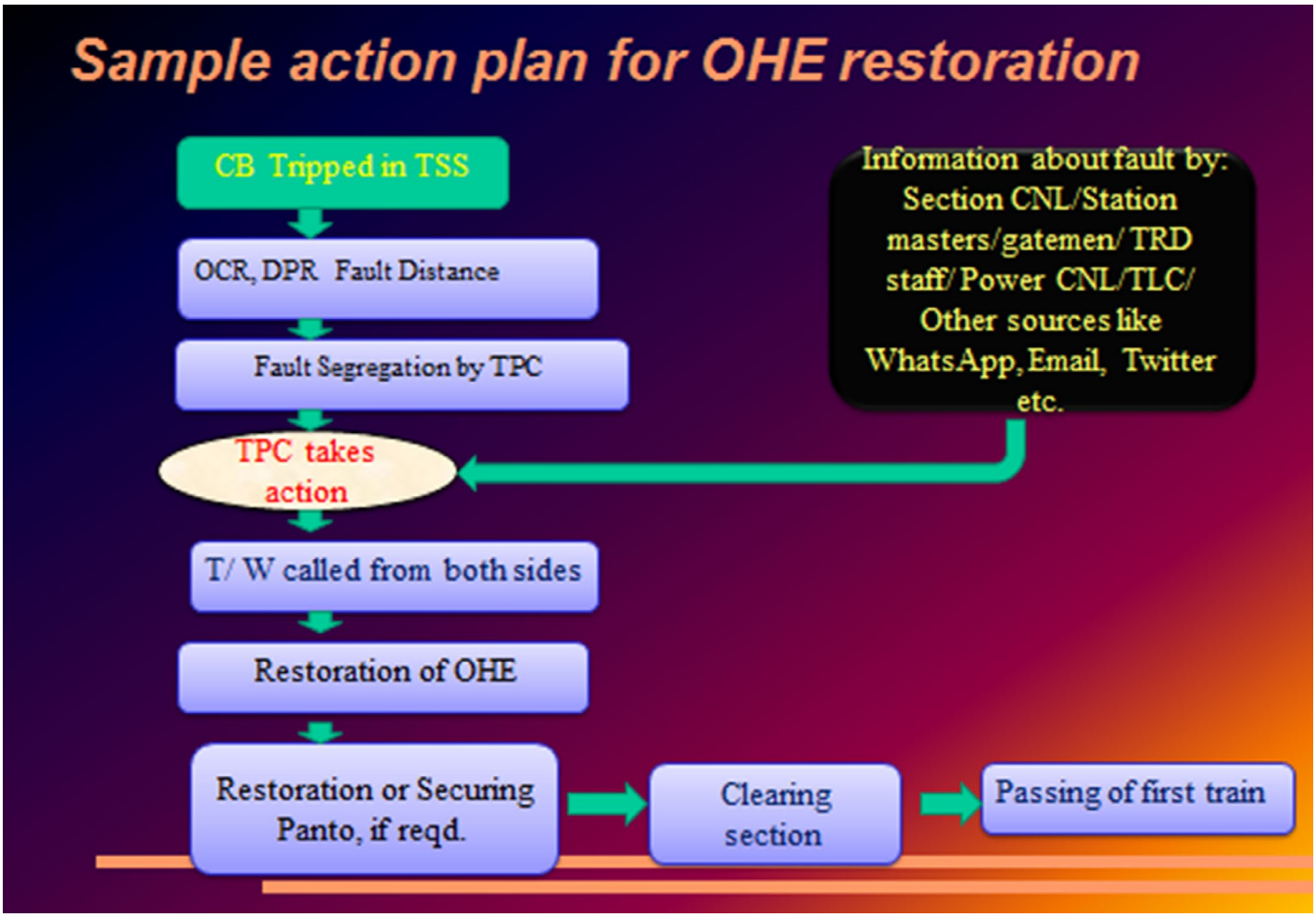
| Sr. No. | Important Points | Remarks |
|---|---|---|
| 1 | One of the most important reasons for the on/delayed operation of distance protection relays is that effective impedance (with predominantly resistive arc component), as seen by the relay, falls outside the parallelogram characteristics as depicted in the diagram below.<br><br> | Condition/availability of earthing bonds at fault location should be checked, especially structure bond, Z/bond, longitudinal bond (continuity), interrail bond and inter-track bonds.<br>If possible, earthing resistance can also be measured at the fault location. The condition of bond joints with Rail should be carefully examined for signs of arcing, loose connections etc.<br>If repeated cases of high impedance faults are observed from a single TSS, then substation buried Rails, and their connections to the Rails must also be checked. |

| Sr. No. | Important Points | Remarks |
|---|---|---|
| 2 | Check how many times CB has been closed by TPC for fault localization. Repeated closing of CB under persisting fault conditions may also result in damage to the system. | A fault localization control card should be readily available with TPC's in line with Para 20522 of ACTM Vol-II Part-I. While preparing the control card, due consideration should be given to quick isolation of tripping prone loco sheds, yard lines.<br>Fault isolation is a must, and direct closing of CB under fault conditions should be prohibited, even if there is a delay of few seconds in the process.<br>An apprentice shall not be deputed as TPC independently as he/she may commit mistakes in feed extension as well as in another sequence of operations during the short time of decision making.<br>Proper training of TPCs should be periodically imparted. TPCs should be made aware of the actual site condition of assets in regard to supply to OHE from the field supervisor. |
| 3 | Verification of the relay settings & calculations done earlier. | Examine if in the recent past changes have been made in the feeding arrangements or layouts. |
| 4 | Distance of fault location from feeding post. | Fault currents are nearer the feeding point.<br>Hence, more attention is needed in the case of smaller fault distances(DPR) exhibited by CBS. |
| 5 | Type of Delta - I relay provided. | Check whether scalar or vectorial Δ-I relay is provided. Vectorial Delta - I relay as per RDSO specification no. TI/SPC/PSI/PROTECT/1982 are the latest and have better resolution. |
| 6 | Check the CB tripping time. | It should not be more than 60 ms. |
| 7 | Testing of relays | Check functionality of relays at set values. Also, check the operating time of the relay by a secondary injection test kit.<br>Features like Local Breaker Back up protection must also be checked.<br>Find out errors, if any, in the relay operating values, especially near boundary conditions.<br>Examine the data recorded in the relay (see Para 4.0 above)<br>Also, Primary injection testing of the relay, its calibration and proper wiring should be ensured, and its defects should be meticulously attended to by expert staff and checked by the supervisor thereafter of its intended operation. |
| 8 | Parallel operation of 2x21.6 MVA transformers | Parallel operation of 2x21.6 MVA transformers leads to nearly double the fault current for close-in faults.<br>A new protection scheme suggested by RDSO vide TI/IN/0017 dated July 2008 should be adopted. |
| 9 | Feed condition (normal/extended) at the time of incidence. | If the problem occurs in the extended feed zone, verify the relay setting calculations carefully. |

| Sr. No. | Important Points | Remarks |
|---|---|---|
| 10 | Power block status and its location. | There have been cases reported from some heavily loaded substations wherein power block of one subsector (i.e. say DN line) between TSS & first SSP has resulted in the feeding of complete load current from single line OHE (i.e. UP line in this case), thereby resulting in overloading and melting or damage to OHE/jumpers. |
| 11 | If trippings are during Rainy season/ thundering, heavy wind/storm | OHE voltage during the monsoon period may be kept at medium tap level in TSS. Await of 15 seconds may be worth it before starting fault segregation/isolation. |
| 12 | Flash overs due to breaking of load currents | If a moving loco/train crosses from the live section to the dead section on an IOL at TSS/FP, the resulting flashover may cause a parting of contact/catenary wires.<br>A similar condition may occur on section insulators provided in yards or loco sheds, especially under power block conditions.<br>Even sudden lowering of the pantograph drawing heavy current may also result in arcing and damage to contact/catenary wires.<br>Use of Panto flash over relays must be considered for all TSS/FP having IOL, if available. |

Some Remedies at a glance to avoid TRD failures and avoid CB Trippings:-

- Strict compliance to Maintenance Instruction no. TI/ MI/0050 on "Prevention from Bird Menace on Traction Installations (OHE/PSI)".
- Proper earthing and bonding of OHE along with sound CBs/BMs and control posts.
- Provision of scary arrangements on OHE structures.
- Provision of PVC pipes of 4-inch dia. not to give space for making a nest in fabricated structures.
- Provision of RSJ/BFB type DAs (Drop Arms) in TTC/ Portal booms.
- Removal of bird nests from time to time – Frequency to be increased for removal of bird nests during monsoon season.
- Some arrangements to be made at boom splices of portals that are just above the cantilevers to avoid bird nesting.
- Increasing the clearance between catenary wire and bottom face of FOB/ROB
- Providing arcing horns in split fashion in AT for minimizing the cases of crow fault.
- Shortening the length of bracket tube and making more clearance from boom with encumbrance adjustment.
- Modification to cantilever chair on platforms at critical locations, i.e. gap to be increased/9-ton insulator to be provided




The above article deals with the problem and solutions related to CB trippings and summarizes the experience gained so far, along with instructions issued so far by HQ/RDSO. Readers will find it helpful in reducing the CB trippings, thereby increasing the reliability of OHE.

IRIEEN JOURNAL

# MOBILE APPLICATION FOR OHE CANTILEVER DESIGN



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## Abstract:

This article discusses the cantilever's designing parameters and the usefulness of a mobile application needed for the non-uniform design of the same. The article also shows the relation between the Stay Arm length, Bracket tube length, Register Arm length and the parameters A, B, C, D in terms of the suspension Distance, Encumbrance, Height. The relations between these parameters are used to write a script in a language to find the length of Stay Arm length, Bracket tube length, Register Arm length and A, B, C, D parameters.

## 1. INTRODUCTION

Overhead equipment is supported from the mast by a cantilever assembly made of the galvanized steel tubes. These tubes are designed to take the weight of the conductors and the radial tension acting on them. For a better current collection by a pantograph, the sag in the contact wire should be constant. To achieve this cantilever should be of the swivelling type, having an automatic tensioning device at the anchor point. The other design considerations that are to be considered are that it should be lighter in weight to minimize the cost and the load on the structure, and it should provide an allowance for future adjustments when the tracks are to be slewed. It will be ideal if the masts are placed at constant setting distances from the track so that the same component of the bracket, stay arm, register arms etc., can be used over most of the location. But the non-uniform design of the cantilever is required as the setting distances are different at the curves, the types of the cantilever assemblies adopted for the turnouts, diamond crossings and overlaps. Also, during the breakdown, the implantation of an emergency mast at the breakdown site is nonstandard. Due to this, nonstandard implantation erection of cantilever is carried out with trial & error method, and hence it takes a lot of time. After erection normally speed restriction is also imposed. The relationship between the design parameters for different Arms of the Cantilever and the A, B, C, D dimensions depends on the suspension distance, Encumbrance and height (the distance between the upper and the lower setting distance). But the relations between these parameters are very complex, and these calculations cannot be made on the spot at the site.

## 2. PROPOSED SCHEME FOR SCRIPTING MOBILE APPLICATION.

Let us take a look at these complex relation between these parameters,

(For reference of the legends please refer the next page)

$B^2=OI^2-EI^2$

$^2=(L-0.2)^2+(e+0.3-0.156+0.0705)^2-0.112$

Calculation of the Bracket Inclination

$Tan\theta1 = (e+ 0.3+ 0.0705- 0.156) / (L-0.2)$

$\Theta2 = Tan\text{-}1 (0.11/B)$

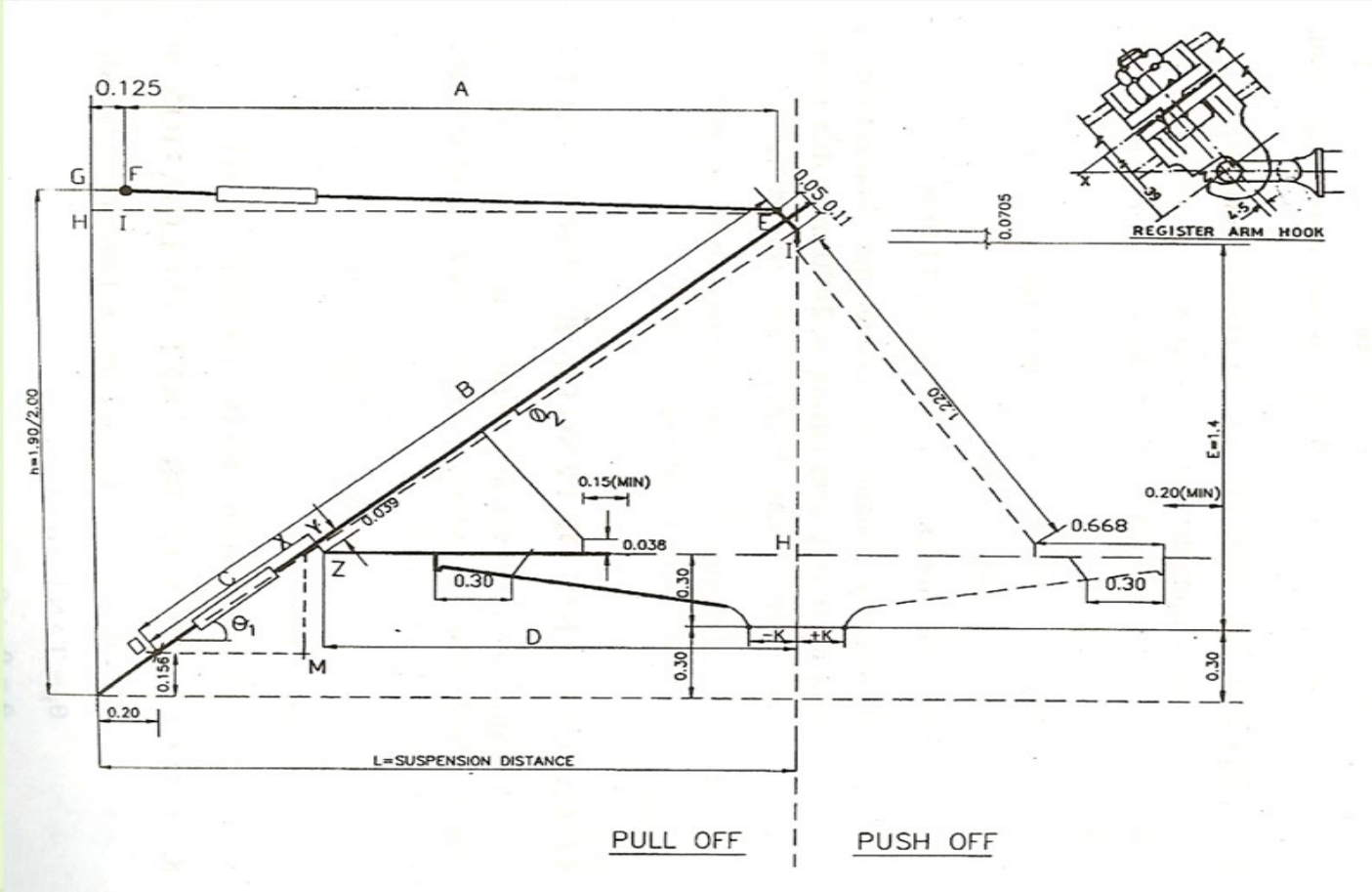
$\Theta = \theta1 + \theta2$

$FE^2= FI^2+IE^2$

If h is the distance between the upper and the lower attachment

FI = h – (0.16Cosθ + 0.0705 + e + 0.3)
IE= L - 0.125 - 0.160Sinθ
A = FE = $(FI^2 + IE^2)^{0.5}$

Determination of C for Register Arm Hook
C= OX + XY+ 0.0045

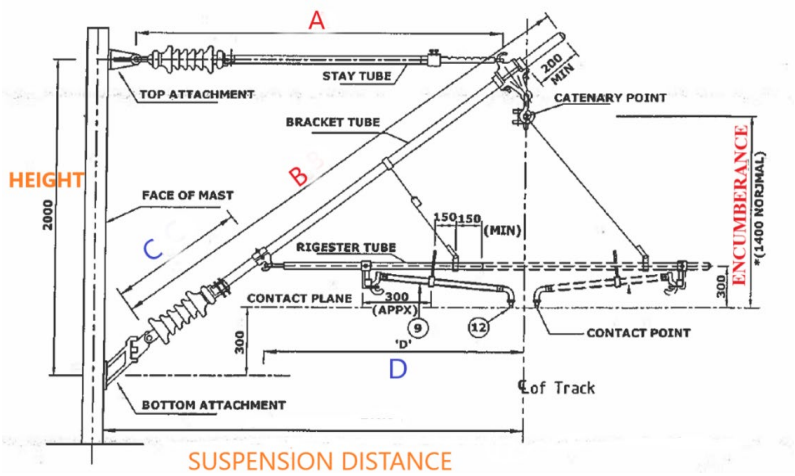



C = MX Cosecθ + YZCotθ +0.0045

C= (0.3+0.3-0.156)Cosecθ + 0.039Cotθ +0.0045

Determination of Distance D
D= L- 0.2 – OM- XZ
D=(L-0.2)-(0.3+0.3-0.156)Cotθ– 0.039 Cosecθ
Stay Arm Length = A- 0.54m (Stay Insulator)
Bracket Tube Length = B+ 0.045+0.083-0.54 m
= (B-0.412) m
Register Arm Length = D-0.1

Earlier, an excel sheet was developed to calculate these dimensions and a booklet in the printed form was available with the RE Organization. But with the change in the technology and to ease the working on the site during the breakdown condition, a Mobile Application was the need of the hour. With the present technology, i.e., the correct size of the cantilever tubes can be calculated with just a click by an App. A mobile application has been developed and complex relations between the parameters programmed for a user-friendly application. The Mobile application can provide accurate results of the A, B, C, D dimensions by giving the values of suspension distance, Encumbrance, Height (the distance between the upper and the lower attachments). These parameters are highlighted in the diagram below.



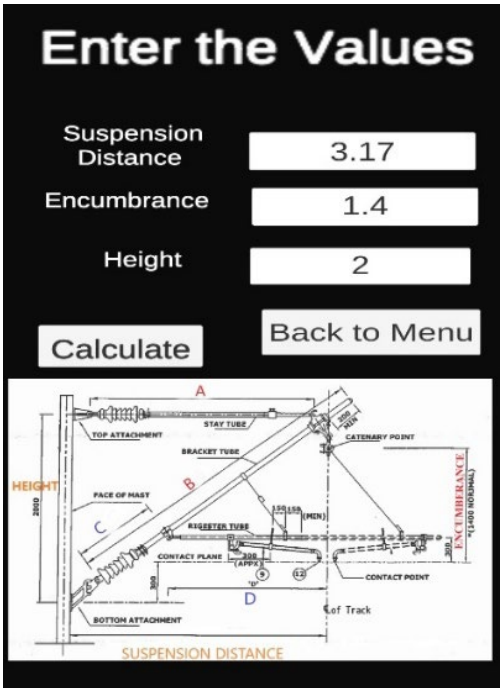




The mobile application is developed in the software called unity. This software is used to develop gaming applications in 2D & 3D modes. The application is designed in a user-friendly manner wherein there are three pages, as shown below.

The first page will be the menu page that displays IRIEEN Logo and the heading "OHE Cantilever Design". There are two tabs—one with evaluation and the other with the Credits option. On clicking the evaluate tab, the second screen pops up as shown. This scene demands the inputs of the suspension distance, Encumbrance and height (the distance between the upper and the lower attachments).




The second image shows the scene that pops up once the evaluate tab is clicked. Here the inputs for the suspension distance, Encumbrance, Height is to be fed in. The image shown in the scene displays the legends for these parameters, providing the users with the clarity of what these required parameters signify. The Last scene depicts the end results. It provides us with the dimensions of the Stay Arm, Bracket tube, Register Arm and the dimensions of A, B, C, D.

Let us take a look at one of the programming is required to generate the results.

```
Using System. Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using UnityEngine.SceneManagement;
public class equation1: MonoBehaviour
{ public InputField variableA;
```

```
 public InputField variableB;
 public InputField variableh;
 public Text variableOutput;
 public Text variableOutput1;
 public Text variableOutput2;
 public Text variableOutput3;
 public Text variableOutput4;
 public Text variableOutput5;
 public Text variableOutput6;
 public GameObject mainCanvas;
 public GameObject outputCanvas;
 // Start is called before the first frame update
 void Start ()
 { mainCanvas.SetActive(true);
  outputCanvas.SetActive(false);  }

 // Update is called once per frame
 void Update()
 {if (Application.platform == RuntimePlatform.Android)
}
   {  if (Input.GetKeyUp(KeyCode.Escape))
    { SceneManager.LoadScene(«Menu»,
LoadSceneMode.Single);  }
      public void compute()
    outputCanvas.SetActive(true);

   float L = float.Parse(variableA.text);
   float e = float.Parse(variableB.text);
  float h = float.Parse(variableh.text);

   float B = Mathf.Sqrt(Mathf.Pow(L-
(float)0.2,2)+Mathf.Pow((e+(float)0.2145),2)-
(float)0.0121);
   float theta1= Mathf.Atan((e+(float)0.2145)/(L-
(float)0.2));
   float theta2= Mathf.Atan((float)0.11/B);
   float theta=theta1+theta2;
   float FI= h-((float)0.16*Mathf.Cos(theta) +
(float)0.0705+e+(float)0.3);
   float IE= L-(float)0.125-(float)0.16*(Mathf.Sin(theta));
   float A= Mathf.Sqrt(Mathf.Pow(FI,2)+Mathf.
Pow(IE,2));
   float C=((float)0.3+(float)0.3-(float)0.156)*Mathf.
Pow((Mathf.Sin(theta)),-1)+(float)0.039*Mathf.
Pow((Mathf.Tan(theta)),-1)+(float)0.0045;
   float D=(L-(float)0.2)-((float)0.3+(float)0.3-
(float)0.156)*Mathf.Pow((Mathf.Tan(theta)),-1)-
((float)0.039*Mathf.Pow((Mathf.Sin(theta)),-1));
   float SA= A-(float)0.54;
   float BT= B-(float)0.412;
   float RA= D-(float)0.15;
   // float output =   Mathf.Pow((L2),2)+Mathf.ACos(e);
   variableOutput.text = SA.ToString(«0.000»);
   variableOutput1.text = BT.ToString(«0.000»);
   variableOutput2.text = RA.ToString(«0.000»);
   variableOutput3.text = A.ToString(«0.000»);
   variableOutput4.text = B.ToString("0.000");
   variableOutput5.text = C.ToString(«0.000»);
   variableOutput6.text = D.ToString(«0.000»);
  public void loadMenuScene()
 {  SceneManager.LoadScene(«Menu»,
LoadSceneMode.Single); }
  public void closeOutput()
  { outputCanvas.SetActive(false);  }
```

This App does not supersede any RDSO Guidelines, and therefore, users are requested to refer to the latest guidelines before using it. For convenience to users, this App has been uploaded to the IRIEEN website with the following address: 10.151.2.19:8081. After incorporating the suggestions from the users, its updated version shall be uploaded to the same website. Users shall find it quite handy, and it is suggested that their printed sheet of cantilever design may be verified with this App.

## 6.Conclusion

A mobile application was developed which provides the correct values of the stay arms length, register tube length, bracket tube length with the variable suspension distance,

## 7.Acknowledgments

This development of the mobile application was supported by the Indian Railway Institute of Electrical Engineering.

## 8. References-

**Principles of design of 25kV AC overhead equipment by PSS RAO**

# अग्निशमन यंत्र एवं बचाव



**शेख शौकत,**
**कनिष्ठ अनुवादक, इरीन**

अग्निशमन यंत्र के प्रकार :- अग्निशमन यंत्र मुख्यत: पाँच प्रकार के होते है :

**1.सोडा एसिड टाइप**

**2.फ़ोम टाइप**

**3.कार्बन डाई-ऑक्साइड**

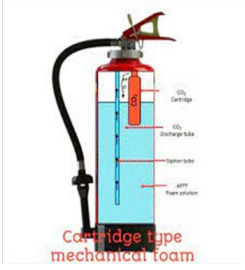
**4.ड्राई केमिकल पाउडर**

**5. अन्य तरीके जैसे - रेत की बाल्टी , पानी द्वारा, स्प्रिंकल द्वारा, फ़ायर ब्रिगेड ।**

1. **सोडा एसिड टाइप : -** इसकी पहचान यह है कि यंत्र मे नोजल बाडी के साथ लगा रहता है। ऊपर में लगे प्लंजर मे कैप लगी रहती है । यह शुष्क आग (Dry fier) को बुझाने के लिए उपयोग किया जाता है । इसमे पानी मिश्रित सोडियम बाइ-कार्बेनेट गैस पैदा होती है। और इससे बनी झाग 20 से 25 फ़ीट दूर तक की आग को बुझाने के काम आती है। यह विद्युतीय आग के लिए यह उपयोगी नहीं है ।।



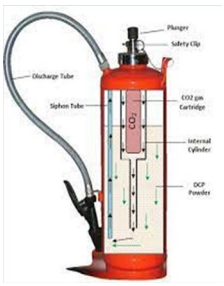

2. **फ़ोम टाइप :-** इसमें नोजल कैप के साथ लगाया जाता है बाडी के साथ नहीं । कैप में लॉकिंग व्यवस्था होती है । यह विशेष रूप से द्रव एवं तेल से संबंधित आग ( बी श्रेणी ) को बुझाने के लिए उपयोग किया जाता है। इसके झाग में विद्युत चालकता के होने के कारण विद्युतीय आग बुझाने के लिए उपयोगी नही हैं। ए-श्रेणी आग में भी उपयोग किया जा सकता है एवं इसका रेंज 20 से 25 फ़ीट तक होती है।




3. **कार्बन डाई-आक्साईड :($Co_2$) :-** इसका आकार गैस सिलेंडर जैसे होता है, डिस्चार्ज ट्यूब के साथ हार्न लगा रहता है। 3 से 15 पाउंड क्षमता के मिलते है। इसकी रेंज 8 से 10 फ़ीट होती है । यह व्यक्तिगत आग के अलावा सभी मौके पर इस्तेमाल हो सकता है एवं किसी वस्तु में क्षति या कोई धब्बा आदि नहीं छोड़ता है ।



4. **ड्राई केमिकल पावडर ( D.C.P) :-** इसमें डिस्चार्ज ट्यूब में ट्रिगर वाल्व लगा रहता है । कैप में प्रेशिंग डिवाइस लगी होती है । यह विशेष रूप से विद्युत आग बुझाने के लिए सीधे उपयोग किया जा सकता है। यह व्यक्तिगत आग के अलावा सभी मौके पर इस्तेमाल हो सकता है। इसका रेंज 4 मीटर तथा प्रेशर 50 पी.एस.आई होता है । इसमे सोडियम बाई कार्बोनेट 97%, मैग्निशियम स्टीरेट 11/2%, मैग्निशियम कार्बोनेट 1%, ट्राई कैल्शियम फ़ास्फ़ेट 1/2%, इस केमिकल के मिश्रण को पावडर के रूप मे दो कन्टेनर मे रख दिया जाता है। कार्बन डाई आक्साइड गैस सिलिन्डर, अन्दर के कन्टेनर में रखा जाता है।



5. **अन्य तरीके - अ) रेत द्वारा-** बाल्टी में रेत भरकर रख दिया जाता

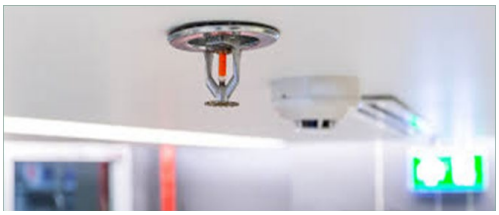
है। आवश्यकता पड़ने पर आग पर रेत फेककर आग को बुझाया जा सकता है।




**ब) पानी द्वारा :-** इसमें ऊंची-ऊंची बिल्डिंगों/ कमर्शियलों, मॉल, शो रुम में लगने वाली आग को बुझाने के लिए प्रत्येक बिल्डिंग में एक होज पाइप बिल्डिंग की टंकी से जुड़ा रहता है जब भी इमरजेंसी होती है तो तुरंत उसका प्रयोग किया जाता है।



**स) स्प्रिंकल द्वारा--** इसका अधिकतर होटलों, दुकानों एवं शो रूम में लगने वाली को बुझाने के लिए किया जाता है। जहां कहीं भी धुंआ उठता दिखाई देता है वहीं पर यह एक आलार्म की तरह काम करता है और फिर पूरे कमरे में पानी की बौछारें छोड़ने लगता है। जिससे पूरे कमरे में लगी आग बुझ जाती है



**द) फ़ायर ब्रिगेड :-** यह एक मशीन है जो पानी को आग पर अधिक दबाव के साथ 50 से 100 फ़ीट रेंज से छिड़कने का काम करती है। इस मशीन में एक पाइप स्टैन्ड होता है जिसकी ऊंचाई 2 से 3 फ़ीट होती है। इसमें लगे हुए डिलीवरी हॉज पाइप की लम्बाई 50 से 100 फ़ीट होती है। मशीन के ब्रांच पाइप का आखिरी भाग में जेट फ़िट किया रहता है। और वाल्व को खोलने या बन्द करने के लिए एक हाइड्रेन्ट चाबी होती है।।




## प्रथमोपचार (First Aid)

**प्रथम उपचार:-** इसका अर्थ है वह सहायता जो किसी आकस्मिक दुर्घटना के समय पीडित या रोगी के जीवन की रक्षा के लिए शीघ्र और सही सहायता डॉक्टर के पास या अस्पताल पहुँचने के बीच की जाती है। जब भी कोई दुर्घटना होती है तो पीड़ित मनुष्य के जीवन को खतरा हो जाता है और पहले साठ मिनट (First Golden Hour) जीवन की रक्षा के लिए बहुत ही महत्वपूर्ण होता है। व्यक्ति को चोट या विद्युत का झटका लगने पर प्रथमोपचार करना अतिआवश्यक है यदि अस्पताल नजदीक हो तो तुरंत व्यक्ति को दवाखाना में ले जाना चाहिए।

व्यक्ति को चोट लगने पर प्राथमिक तौर पर घाव को धोकर, टिटनेस का इंजेक्शन लगाना चाहिए एंव पट्टी करने के उपरांत घायल व्यक्ति को अस्पताल भेजना चाहिए।।

## विद्युत दुर्घटना पर कार्यवाही

1. विद्युत सप्लाई तुरन्त बन्द कर दें।
2. व्यक्ति को बिजली के तार से अलग करें।
3. मरीज को खुले हवादार प्रकाश मान कमरे मे बिठाएं या लिटाएं।
4. व्यक्ति को सुखे स्थान पर लिटाकर ही कृत्रिम श्वास का तरीका अपनाना चाहिए। बिना समय नष्ट किये मुँह से मुँह में हवा भरके कृत्रिम श्वास देना चाहिए।
5. घायल व्यक्ति प्रथमोपचार के तुरंत बाद अस्पताल में तुरंत भेजना चाहिए।
6. गरम तार से अलग होने के पश्चात, यदि कपडों से चिंगारी आदि निकल रही हों तो उन्हें बुझाकर कपड़े बदल देना चाहिए।
7. आग के समय अग्निशमन उपकरण का इस्तेमाल करें।
8. सभी संबंधित अधिकारियों को सूचना दें।

## चोट लगने पर उपचार

1. बैन्डेज लगाये।
2. खून का बहाव कम करने का उपाय करे।
3. हड्डी टूटी हो तो उस अंग को न हिलाएं।

4. चोट लगी जगह को डिटाल से साफ करे।
5. मरीज की मालिस करके शरीर को गर्म करे।
6. मरीज को चाय पिलाएं।
7. मरीज को अतिशीघ्र डॉक्टर के पास ले जाएं।

## जलने पर किये जाने वाला उपचार :-

मरीज की जली हुई जगह पर आलू का पानी, बर्नाल, नारियल तेल आदि का प्रयोग करें। 10 ग्राम खाने वाला सोडा आधा लीटर पानी में मिलाकर घोल बना लें फ़िर कपड़ा भीगोकर चोट के ऊपर ढक दें, आराम मिलेगा, ठंडा पानी पिलाएं। रोगी बेहोश हो तो उसे होश मे लाने का प्रयास करें।

## कार्य स्थल का पर्यावरण एवं स्वच्छता

**(क) सामग्री का भंडारण(Storage)**

1. सामग्री का भंडारण रूम ऐसा होना चाहिए कि उसमें उचित प्रकाश, वेन्टीलेशन की पर्याप्त व्यवस्था हो साथ ही नमीरहित होना चाहिए।
2. विभिन्न प्रकार की सामग्री के लिए अलग-अलग भागों की व्यवस्था होनी चाहिए।
3. भंडारण में सामग्री में आग लगने से बचाव हेतु उपाय सुनिश्चित करें। स्टोर रूम फायर प्रुफ एवं उसमें अग्निशामक यंत्रों की समुचित व्यवस्था होनी चाहिए एवं कोई भी एक्सपाइरी डेट के अग्निशामक यंत्र स्टोर में नहीं रखने चाहिए अन्यथा वे समय पर धोखा दे सकते हैं।
4. रबर एवं आग से प्रभावित होने वाली सामग्री को अलग स्थान पर स्टोर करना चाहिए।
5. विद्युत, यांत्रिक, भंडारण के लिए अलग-अलग कक्ष की व्यवस्था होनी चाहिए।
6. पेन्टस, केबल आदि फायर प्रूफ स्थानों पर स्टोर करना चाहिए।
7. सामग्री निर्धारित जगह पर रखना चाहिए।
8. कार्य स्थल पर कैरिडोर, गैलरी, रास्ता आदि साफ रखना चाहिए।
9. सामग्री पर जंग आदि से बचाव के लिए उपाय होना चाहिए।
10. सामग्री की चोरी रोकने के लिए सुरक्षित स्थान पर स्टोर करें।
11. सामग्री सही स्थान पर सही तरीके से रखने से सर्विस में सुविधा होती है तथा सामग्री का क्षतिग्रस्त होने से बचाव होगा और दुर्घटनाएं टल सकती है।

**(ख) कार्य स्थल की स्वच्छता(Cleanliness)**

1. कार्यस्थल पर कार्य आरम्भ करने एवं कार्य समाप्त करने के पश्चात प्रतिदिन सफाई करना आवश्यक है।
2. कार्यस्थल के बेंच, जीना (सीढी), रास्ता आदि प्रतिदिन साफ करना चाहिए। फर्श आदि को सप्ताह में एक बार पानी से अवश्य धोना चाहिए। कार्य करते समय आवश्यक सामग्री को सही प्रकार से बनी ट्रे में रखकर कार्य करना चाहिए।
3. कार्य करने के दौरान यह ध्यान रखना चाहिए कि ग्रीस, ऑयल फर्श पर न गिरे इसके लिए मशीन के भागों से ग्रीस या ऑयल गिरने वाले स्थानों पर ट्रे का प्रयोग करना चाहिए और मशीनों को समय-समय पर जूट के कपड़े से साफ करते रहें।
4. तेल से भीगे हुए वस्तु एवं अन्य कचरा डस्टबिन (कूढेदान) में डालने का ध्यान रखें।
5. जॉब बनाने के दौरान यदि कोई वेस्ट सामग्री निकलती है तो उसे रखने हेतु उचित आकार के डिब्बे बने होने चाहिए।
6. जॉब बनाने के दौरान कटिंग सामग्री को अलग-अलग डिब्बों में रखना चाहिए जैसे कॉपर तथा आयरन के लिए अलग-अलग डिब्बों की व्यवस्था होनी चाहिए।
7. नालियों की सफ़ाई समय-समय पर होनी चाहिए।
8. कार्यस्थल पर हवा एवं रोशनी पर्याप्त मात्रा में होनी चाहिए।
9. हर माह में एक बार पूरे स्टोर की सफाई होनी चाहिए।
10. हर 5 साल में एक बार पेंटिंग/कलरिंग होनी चाहिए।

# शब्दों का संसार



संकलनकर्ता
**श्री राधेश्याम गुर्जर**
कनिष्ठ अनुवादक, इरीन, नाशिक रोड

शब्द रचे जाते हैं,
शब्द गढ़े जाते हैं,
शब्द मढ़े जाते हैं,
शब्द लिखे जाते हैं,
शब्द पढ़े जाते हैं,
शब्द बोले जाते हैं,
शब्द तोले जाते हैं,
शब्द टटोले जाते हैं,
शब्द खंगाले जाते हैं,

*अंततः*

शब्द बनते हैं,
शब्द संवरते हैं,
शब्द सुधरते हैं,
शब्द निखरते हैं,
शब्द हँसाते हैं,
शब्द मनाते हैं,
शब्द रूलाते हैं,
शब्द मुस्कुराते हैं,
शब्द खिलखिलाते हैं,
शब्द गुदगुदाते हैं,
शब्द मुखर हो जाते हैं,
शब्द प्रखर हो जाते हैं,
शब्द मधुर हो जाते हैं,

*फिर भी-*

शब्द चुभते हैं,
शब्द बिकते हैं,
शब्द रूठते हैं,
शब्द घाव देते हैं,
शब्द ताव देते हैं,
शब्द लड़ते हैं,
शब्द झगड़ते हैं,
शब्द बिगड़ते हैं,
शब्द बिखरते हैं
शब्द सिहरते हैं,

*किंतु-*

शब्द मरते नहीं,
शब्द थकते नहीं,
शब्द रुकते नहीं,
शब्द चूकते नहीं,

*अतएव-*

शब्दों से खेले नहीं,
बिन सोचे बोले नहीं,
शब्दों को मान दें,
शब्दों को सम्मान दें,
शब्दों पर ध्यान दें,
शब्दों को पहचान दें,
ऊँची लंबी उड़ान दे,
शब्दों को आत्मसात करें...
उनसे उनकी बात करें,
शब्दों का अविष्कार करें...
गहन सार्थक विचार करें,

*क्योंकि-*

शब्द अनमोल हैं...
ज़ुबाँ से निकले बोल हैं,
शब्दों में धार होती है,
शब्दों की महिमा अपार होती,
शब्दों का विशाल भंडार होता है,

***और सच तो यह है कि-***
***शब्दों का अपना एक संसार होता है***

# ढाई अक्षर का प्रेम



संकलनकर्ता
**महेश मानकर**
तकनीशियन -।,इरीन, नाशिक रोड

ढाई अक्षर प्रेम का
पढ़े सो पंडित होय

ये ढाई अक्षर क्या है-

ढाई अक्षर के ब्रह्मा
और ढाई अक्षर की सृष्टि।

ढाई अक्षर के विष्णु
और ढाई अक्षर की लक्ष्मी।

ढाई अक्षर के कृष्ण
और ढाई अक्षर की कान्ता
ढाई अक्षर की दुर्गा
और ढाई अक्षर की शक्ति।
ढाई अक्षर की श्रद्धा
और ढाई अक्षर की भक्ति।
ढाई अक्षर का त्याग
और ढाई अक्षर का ध्यान।

ढाई अक्षर की तुष्टि
और ढाई अक्षर की इच्छा।

ढाई अक्षर का धर्म
और ढाई अक्षर का कर्म।
ढाई अक्षर का भाग्य
और ढाई अक्षर की व्यथा।

ढाई अक्षर का ग्रन्थ,
और ढाई अक्षर का सन्त।
ढाई अक्षर का शब्द
और ढाई अक्षर का अर्थ।
ढाई अक्षर का सत्य
और ढाई अक्षर की मिथ्या।

ढाई अक्षर की श्रुति
और ढाई अक्षर की ध्वनि।
ढाई अक्षर की अग्नि
और ढाई अक्षर का कुण्ड।
ढाई अक्षर का मन्त्र
और ढाई अक्षर का यन्त्र।

ढाई अक्षर की श्वांस
और ढाई अक्षर के प्राण।
ढाई अक्षर का जन्म

ढाई अक्षर की मृत्यु।
ढाई अक्षर की अस्थि
और ढाई अक्षर की अर्थी।

ढाई अक्षर का प्यार
और ढाई अक्षर का युद्ध।

ढाई अक्षर का मित्र
और ढाई अक्षर का शत्रु।

ढाई अक्षर का प्रेम
और ढाई अक्षर की घृणा।

जन्म से लेकर मृत्यु तक
हम बंधे हैं ढाई अक्षर में।
हैं ढाई अक्षर ही वक़्त में,
और ढाई अक्षर ही अन्त में।
समझ न पाया कोई भी
है रहस्य क्या ढाई अक्षर में।



संकलनकर्ता
**श्रीमती वैशाली.एस.पाटिल**
खलासी, इरीन, नाशिक रोड

*हिंदी*
हमारी *हिंदी*
राष्ट्र भाषा है *हिंदी*
हिन्द देश की आन है *हिंदी*
संस्कृत की लाडली बेटी है *हिंदी*
हिंदुस्तान की तो मातृभाषा है *हिंदी*
हमारा मान,सम्मान,अभिमान है *हिंदी*
हिंदुस्तान के माथे की तो बिंदी है यह *हिंदी*
सुंदर, मीठी, सरल और सहज भाषा है *हिंदी*
हम सबकी एकता की अनुपम परंपरा है *हिंदी*
सब जन को एकसूत्र में पिरोने वाली डोर है *हिंदी*
काल को जीत लिया वो कालजयी भाषा है *हिंदी*
स्वतंत्रता की अलख जगाने वाली भाषा है *हिंदी*
जिसके बिना हिंद थम जाए वो भाषा है *हिंदी*
गुलामी की जंजीर तोड़ने वाली थी *हिंदी*
हिंदुस्तान की तो जीवन रेखा है *हिंदी*
वीर सपूतों की लाडली थी *हिंदी*
स्वतंत्रता की कहानी है *हिंदी*
पराई नहीं अपनी है *हिंदी*
आपकी भी है *हिंदी*
मेरी भी है *हिंदी*
सबकी *हिंदी*
हिंदी *हिंदी*
*हिंदी*

## कार्यालय में प्रतिदिन प्रयोग में आने वाली नेमी टिप्पणियां (Routine Notings)

| | | |
|---|---|---|
| 1 | Accord approval/Sanction | कृपया अनुमोदन/मंजूरी प्रदान करें। |
| 2 | Action at once only | कृपया तुरंत कार्रवाई करें। |
| 3 | Address all concerned | सर्व संबंधित को लिखा जाए। |
| 4 | All concerned to note | सर्व संबंधित नोट करें। |
| 5 | As a special case | विशेष मामले के रूप में। |
| 6 | As early as possible | यथाशीघ्र/जितनी जल्दी हो सके। |
| 7 | As per extent orders | वर्तमान आदेशों के अनुसार। |
| 8 | Call for explaination | स्पष्टीकरण मांगा जाए। |
| 9 | Carry out orders | आदेश का पालन करें। |
| 10 | Continue in office | पद पर बने रहना। |
| 11 | Duly verified | विधिवत् सत्यापित। |
| 12 | Enquiry has been ordered | जांच का आदेश दिया गया है। |
| 13 | Estimate is under preparation | प्राक्कलन तैयार किया जा रहा है। |
| 14 | Ex-gratia payment | अनुग्रह के रूप में भुगतान। |
| 15 | Ex-parte judgement | एकपक्षीय निर्णय। |
| 16. | Ex-post facto sanction | कार्योत्तर मंजूरी। |
| 17 | Failing which | ऐसा न करने पर। |
| 18 | Fix a date for meeting | बैठक के लिए तारीख नियत करें। |
| 19 | For further action | अगली कार्रवाई के लिए। |
| 20 | For information only | केवल सूचना के लिए। |
| 21 | General manager's sanction is necessary | महाप्रबंधक की मंजूरी आवश्यक है। |
| 22 | Give details | विस्तृत जानकारी दें। |
| 23 | Give top priority | सर्वोच्च प्राथमिकता पर। |
| 24 | Held in abeyance | आस्थगित रखा जाए। |
| 25 | Immediate action please | तत्काल कार्रवाई करें। |
| 26 | In any special case | किसी मामले विशेष में। |
| 27 | In confirmation….. | .....की पुष्टि में। |
| 28 | In connection with | .....के संबंध में। |
| 29 | In exercise of | का प्रयोग करते हुए। |
| 30 | In lieu of | के बदले में। |
| 31 | It is suggested that | सुझाव है कि। |
| 32 | Joined duly | कार्यभार ग्रहण किया। |
| 33 | Justify your proposal | अपने प्रस्ताव का औचित्य दें। |
| 34 | Keeping in view | दृष्टि में रखते हुए। |
| 35 | Keep pending | यथा प्रस्तावित स्वीकृति/मंजूर |
| 36 | Kindly accord concurrence | कृपया सहमति प्रदान करें। |
| 37 | Kindly confirm | कृपया पुष्टि करें। |
| 38 | Leave asked for may be sanctioned | मांगी गई छुट्टी मंजूर की जाए। |

| | | |
|---|---|---|
| 39 | Look into the matter | मामले को देखें। |
| 40 | Matter has been considered | मामले पर विचार किया गया है। |
| 41 | Matter is under investigation | मामले की जांच की जा रही है। |
| 42 | May be approved | अनुमोदित किया जाए। |
| 43 | May be regretted | खेद प्रकट किया जाए। |
| 44 | May be treated as urgent | अति आवश्यक समझा जाए। |
| 45 | Must be adhered to | कड़ाई के साथ पालन किया जाए। |
| 46 | Necessary action may be taken | आवश्यक कार्रवाई की जाए। |
| 47 | Noted and returned | नोट करके वापिस किया जाता है। |
| 48 | Not satisfactory | संतोषजनक नहीं है। |
| 49 | On behalf of | की ओर से। |
| 50 | On deputation | प्रतिनियुक्ति पर। |
| 51 | Order may be issued | आदेश जारी कर दिया जाए। |
| 52 | Placed under suspension | निलंबित किया गया। |
| 53 | Please circulate | कृपया परिपत्रित करें। |
| 54 | Please confirm(position) | कृपया (स्थिति) की पुष्टि करें। |
| 55 | Please expedite compliance | शीघ्र अनुपालन कीजिए। |
| 56 | Please speak | कृपया बात करें। |
| 57 | Proposal accepted | प्रस्ताव स्वीकार है। |
| 58 | Put up for perusal please | अवलोकनार्थ प्रस्तुत। |
| 59 | Quash the proceedings | कार्यवाही रद्द कर दें। |
| 60 | Question of propriety | औचित्य का प्रश्न। |
| 61 | Quote reference | संदर्भ बताएं। |
| 62 | Reasons for delay be explained | देरी होने के कारण बताए जाएं। |
| 63 | Recovery from pay | वेतन से वसूली। |
| 64 | Relinquish charge | कार्य भार छोड़ना। |
| 65 | Sanctioned as proposal | आशोधन की आवश्यकता है। |
| 66 | Seen, thanks | देख लिया, धन्यवाद। |
| 67 | Submitted for approval | अनुमोदनार्थ प्रस्तुत। |
| 68 | Take no action | कोई कार्रवाई न की जाए। |
| 69 | This required administrative approval | इसके लिए प्रशासनिक अनुमोदन आवश्यक है। |
| 70 | Urgent | शीघ्र/तुरंत। |
| 71 | Under consideration | विचाराधीन। |
| 72 | Under intimation to this office | इस कार्यालय को सूचना देते हुए। |
| 73 | Under mentioned | निम्नलिखित। |
| 74 | Undersigned is directed to | अधोहस्ताक्षरी को निदेश हुआ है कि। |
| 75 | Until further orders | अगला आदेश मिलने तक। |
| 76 | Verified & found correct | पड़ताल की और ठीक पाया। |
| 77 | Vide letter no | पत्र सं. ...देखिए |
| 78 | What delays | विलंब क्यों/देरी क्यों हो रही है। |

| | | |
|---|---|---|
| 79 | What is the position | क्या स्थिति है ? |
| 80 | Whichever is earlier | जो भी पहले हो/जो भी पहले घटित हो । |
| 81 | With reference to your letter | आप के उल्लिखित पत्र के संदर्भ में । |
| 82 | Without further delay | आगे और विलंब किए बिना । |
| 83 | With regards | सादर । |
| 84 | Without prejudice | प्रतिकूल प्रभाव डाले बिना । |
| 85 | Your attention is drawn | आपका ध्यान आकर्षित किया जाता है । |
| 86 | Yours faithfully | भवदीय, भवदीया । |
| 87 | Yours sincerely | आपका, भवदीय । |
| 88 | You are hereby informed that | आपको इसके द्वारा सूचित किया जाता है कि । |
| 89 | You are hereby authorised to | आपको इसके द्वारा यह प्राधिकार दिया जाता है कि |
| 90. | Your further remarks/view on the above subject is awaited | उपर्युक्त विषय पर आपकी आगे की टिप्पणी/राय की प्रतीक्षा है । |

**राजभाषा अधिनियम-1963 की धारा 3 की उपधारा 3 के शत-प्रतिशत अनुपालन में-**

1 सामान्य आदेश ,परिपत्र,कार्यालय आदेश, समय- सारणी, आरक्षण चार्ट आदि / **General Orders, Circulars, Office Orders, Time- Table, reservation chart etc.**

2 अधिसूचनाएं **(Notification)** (राजपत्र में प्रकाशित/**Published in the Gazette)**

3 प्रेस विज्ञप्ति / रिलीज **(Press Communiques / Release)**

4 संविदाएं **(Contracts)**

5 अनुबंध **(Agreement)** उद्धरण **(Quotation)**

6 अनुज्ञप्ति **(Licence)**

7 अनुज्ञा पत्र **(Permit)**

8 निविदा **(Tender)** के प्रपत्र **(Form)** और सूचना-विज्ञापन **(Notice)**

9 संकल्प **(Resolution)**

10 नियम **(Rules)**

11 संसद के एक या दोनों सदनों में प्रस्तुत सरकारी कागज पत्र (रिपोर्टों के अलावा) **Official paper papers (other than reports) presented in one or both houses of Parliament**

12 संसद के एक या दोनों सदनों में प्रस्तुत प्रशासनिक अन्य रिपोर्टें **(Administrative other reports presented in one or both houses of Parliament)**

13 प्रशासनिक या अन्य रिपोर्टें (संसद के एक या दोनों सदनों में प्रस्तुत की गई रिपोर्टों के अलावा) / **Administrative or other reports (other than those presented in one or both Houses of Parliament)**

(अ) **'क्षेत्र क'** से बिहार, हरियाणा, हिमाचल प्रदेश, मध्य प्रदेश, छत्तीसगढ़, झारखंड, उत्तराखंड राजस्थान और उत्तर प्रदेश राज्य तथा अंडमान और निकोबार द्वीप समूह, दिल्ली संघ राज्य क्षेत्र अभिप्रेत है;

(ब) **'क्षेत्र ख'** से गुजरात, महाराष्ट्र और पंजाब राज्य तथा चंडीगढ़, दमण और दीव तथा दादरा और नगर हवेली संघ राज्य क्षेत्र अभिप्रेत हैं;

(स) **'क्षेत्र ग'** से खंड (अ) और (ब) में निर्दिष्ट राज्यों और संघ राज्य क्षेत्रों से भिन्न राज्य तथा संघ राज्य क्षेत्र अभिप्रेत है;

# 15 अगस्त 2020 (स्वतंत्रता दिवस) की झलकियां















# हिंदी दिवस/राजभाषा सप्ताह- 2020 की झलकियां
















वाक् प्रतियोगिता
विषय - ऑनलाइन शिक्षण


काव्य/कविता पाठन
प्रतियोगि


भारतीय रेल विद्युत इंजीनियरिंग
संस्थान, नाशिक रोड


भारतीय रेल विद्युत इंजीनियरिंग
संस्थान, नाशिक रोड


भारतीय रेल विद्युत इंजीनियरिंग
संस्थान, नाशिक रोड


भारतीय रेल विद्युत इंजीनियरिंग
संस्थान, नाशिक रोड


भारतीय रेल विद्युत इंजीनियरिंग
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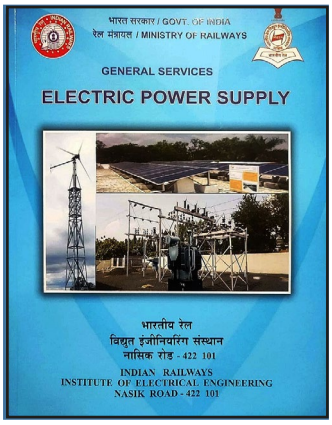
IRIEEN Journal is a quarterly publication. The editorial board of IRIEEN Journal invites practitioners, researchers and other interested persons to contribute articles pertaining to or relevant to the area of Railway Electrical Engineering. The articles can be on relevant technical/ management topics and should help in dissemination of knowledge besides offering new ideas for application in the field. Officers working in Indian Railways acquire a wealth of knowledge and experience as they progress through their careers. It is important that the officers write articles/ papers around their important experiences, contributions and findings on the work front. Such articles/ papers when published in IRIEEN Journal can reach a wide audience and also secure a permanent place in our institutional memory and knowledge base.

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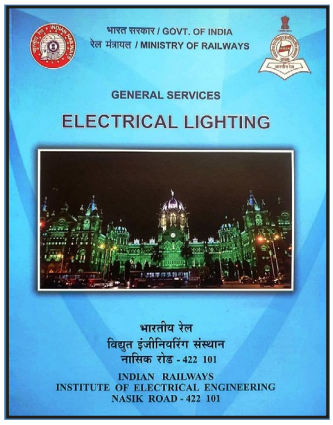
1. Soft copy as well as hard copy of articles must be sent to: Editor, Indian Railways Institute of Electrical Engineering, Nasik Road, Email Id : irieenlib@gmail.com)
2. Author should send the original printout of photograph along with the digital copy of the photograph
3. The paper should be concise (5 to 10 pages). Sketches, tables and figures should be accommodated in a two column set up.
4. The paper's content should be easily comprehensible to the readers.
5. The paper may be a review of conventional electrical technology, possibilities of improvement in the electrical technology or any other items which may be of some interest to the readers. For the guidance of contributors, an indicative (not exhaustive) list of subject areas is as follows :

   (i) Traction Rolling Stock
   (ii) Train Lighting & Air Conditioning
   (iii) General Services
   (iv) Traction Distribution
   (v) Railway Electrification
   (vi) Success stories
   (vii) Management tips to improve working
   (viii) Do's and Don'ts on matters of interest

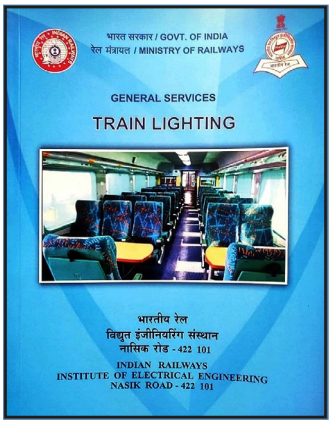
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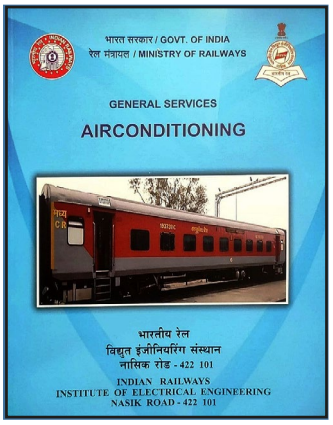

ELECTRIC POWER SUPPLY



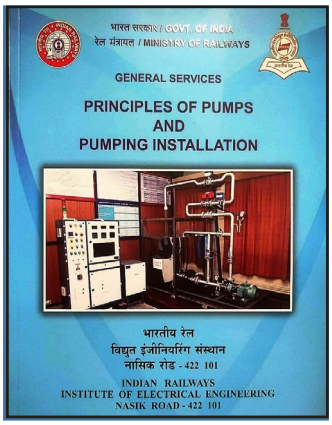

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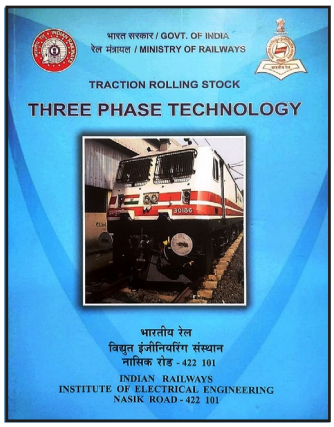

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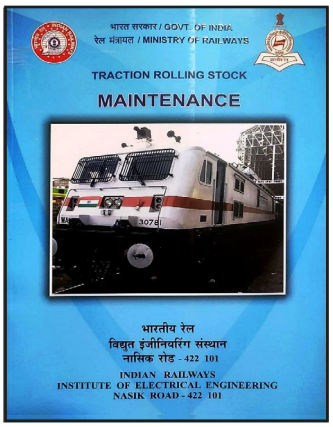

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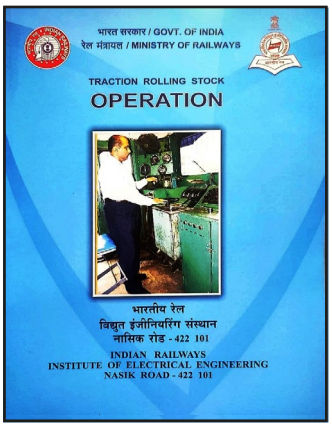

PRINCIPLES OF PUMPS AND PUMPING INSTALLATION



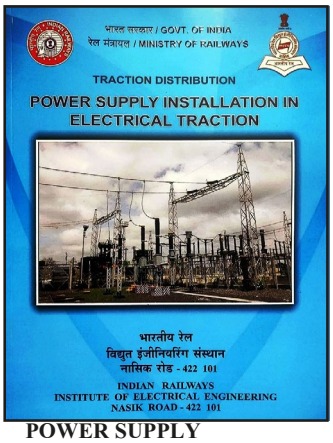

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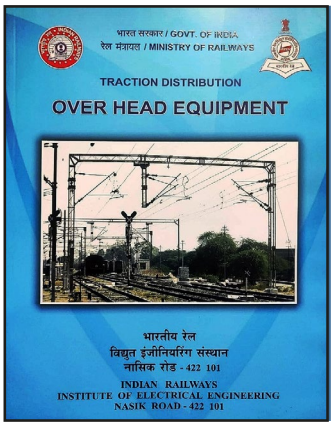

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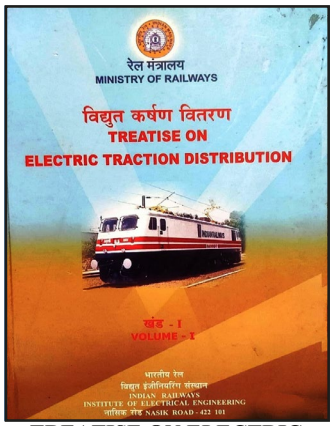

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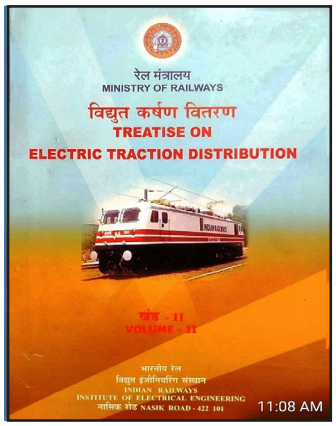

POWER SUPPLY INSTALLATION IN ELECTRICAL TRACTION



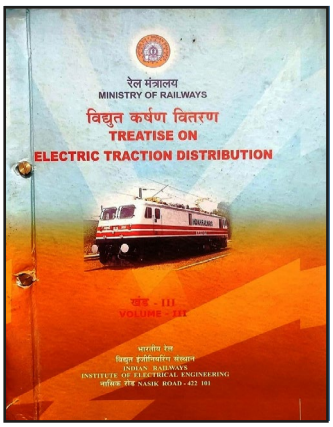

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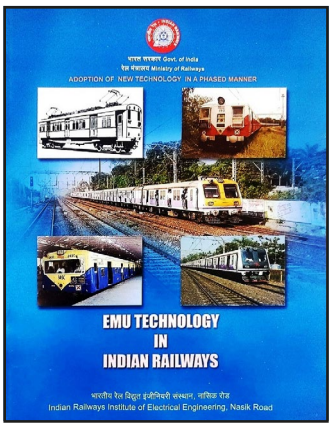

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