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An Evaluation of Downburst Wind Load on Power Transmission Technologies

Abstract: - Transmission tower failures can result in power outages, which can have disastrous social and economic effects. Global transmission line failure investigations have shown that downbursts and tornadoes typically cause high intensity winds that cause transmission line breakdowns. Because downbursts produce long-lasting, intense wind occurrences, they pose the biggest threat. Numerous research works have looked into how these events might be applied to transmission line systems (TLS). Unfortunately, the search of transmission line fails under these kinds of loads has been made more difficult by the large ranges for the various downburst parameters and the diverse "representations of downburst wind speeds", which differ from boundary layer wind profiles. The literature on TLS under downburst wind stresses is reviewed in this work. It investigates downburst wind loads, the structural behaviors of TLS under such stresses, and their modelling models. Static and dynamic analysis, as well as TLS modelling, are reviewed.

Keywords: power transmission, wind speed, downburst, structure, boundary layer.

I. INTRODUCTION

According to Li (2000), severe thunderstorm occurrences involving downburst winds are to blame for over 90%. This pattern is repeated in other parts of the world with similar climatic circumstances. Electricity outages brought on by transmission tower failure can "cause social and economic" catastrophes. Furthermore, a single or two tower collapse can set off a lengthy series of events that could demolish multiple transmission towers at once (Dempsey and White, 1996). Although Savory et al. (2001) presented the first model for isolated transmission towers under localized wind loads, researchers have since studied the structural behavior of complete transmission line systems (TLS) due to the imbalanced distribution of these sorts of loads. These investigations, however, were restricted to stationary downbursts, which are distinct from the transitory downbursts that are more typical of these kinds of occurrences. The downburst velocity in the storm's front is increased by the translation velocity, while the speed in its back is decreased. Additionally, there are theories that the translation speed results in "forward and backward gaps" in horizontal wind distributions, which may lead to varying wind speed distributions on various TLS panels.

Numerous researches examined transmission towers' structural reaction and failure analysis during downburst loads, however largely ignored retrofitting techniques. Transmission tower upgrades can be achieved through the use of various reinforcement techniques, including friction-type reinforcement, diaphragm bracing, leg retrofitting, and x-brace type. Questions need to be answered regarding the effectiveness of these techniques, the ease of reinforcement, the cost, and the best way to distribute reinforcement through the TLS during a downburst.

A fundamental goal of structural design is to ensure structural safety through optimal design; as a result, contemporary TLS needs to be updated to handle this loading scenario. There needs to be conversation about the best or most efficient tower arrangements in TLS as well as the best orientation with regard to wind loads.

Regarding the behaviour of TLS during downbursts, a number of questions are put forth, beginning with modelling downburst events, modelling TLS, applying these kinds of loads, creating design parameters, and retrofitting older towers. This publication offers a thorough analysis of previous research, including the authors' own, followed by a number of recommendations for more study.

2. WIND LOADS DURING A DOWNTURN

Design criteria that rely on the atmospheric transverse wind as the primary source of wind loads expose TLS to the risk of wind events that are localized, including tornadoes and downbursts. Transmission towers are significantly threatened by these two occurrences. Localized wind events are unlikely to occur in a particular area, but when TLS is extended over longer distances, the dangers to the system as a whole increase, raising the possibility that one of these events would cross the transmission line (Holmes et al., 2008). Warm air rises through clouds and then emerges above their summit, forming a dome of warm air, which is known as a downburst. At this point, the air cools and starts to descend, causing the dome to collapse and a burst of harmful air to emerge ('downbursts' of air are dubbed danger to aviation, 1979). The downburst's practical widths are around one kilometre, and the outburst flow's extent ranges from one to six kilometres (Wilson et al., 1984). Based on 11 incidents, Hjelmfelt (1988) demonstrated that the downdraft width varied from 1.5 to

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3.0 km. Downbursts are the most extreme wind type at a height of 10 meters, according to analyses of extreme wind speeds in Australia (Holmes, 2002). According to Boss (2010), there are roughly ten downburst reports for every tornado damage report.

2.1 Modelling of sudden drops in load

Three distinct prototypes have been used to simulate the propagation of "downburst winds": the ring vortex, the impinging jet. Before it touches the ground, the ring vortex model creates a vortex ring. The results from simulated microburst occurrences utilizing a massive impinging jet were more compatible with full-scale data (1999). Although the ring vortex creation has been incorporated into the impinging jet model, these models are unable to explain the buoyancy effects that the cooling source models have been able to (Selvam et al, 1992; Vermeire et al., 2011a). Three methods have been employed in previous research to simulate downburst wind speeds: analytical/empirical models, numerical models, and experimental models. We'll take each of these in turn.

2.2 Models for numerical and experimental simulation

Numerous scholars have carried out both numerical and experimental simulation techniques. An initial innovation simulation for a wall jet was initiated by Bakke (1957). Holmes (1992) and Cassar (1992) used a wind tunnel to model downburst wind speeds; Wood et al. (2001) used impinging jet models for varying embankment heights; and Chay and Letchford (2002) used a stationary wall jet tunnel and a moving downburst in a wind tunnel to study downburst wind profiles (Letchford et al., 2002). The impinging jet models are size dependant, according to Kim and Hangan's 2007 investigation into various downburst scales in wind tunnels. Mason et al. (2009) investigated downburst storms using the cooling source model.. The results of past experiments and numerical simulations are summarized. There are a number of challenges when using experimental or numerical models to apply downburst wind loads on TLS. There are further reservations besides the difficulty of combining experimental or numerical simulation with structural analysis. Scale dependency is one. The scale dependency was verified by Xu and Hangan (2008) and Kim and Hangan (2007) when they assessed the scale impacts for steady state and unsteady state simulation.

2.3 Turbulence component and analytical/empirical models

These components are the radial and vertical speeds. Nevertheless, their model was temporally independent and neglected to account for the outflow ring vortex. Furthermore, there was a notable discrepancy between their profiles and the numerical and field data. The translation speed was provided by Holmes and Oliver (2000), who also permitted downburst degradation over time. Several changes were made to the model by Chay et al. (2006). As a function of radius, they enhanced the maximum wind speed height. An additional enhancement was made by Li et al. (2012) by incorporating the boundary layer growth's nonlinear effects.

Holmes (2001) used the downburst which was observed at the Andrews Naval Base in Washington, D.C., in 1983 to calculate the disturbance intensity, which is equivalent to 0.1 times the non-turbulent wind speed, or a(z; t) = 0.1U (z; temp. Holmes and several other scientists used experimental, numerical, and field events to compute the turbulence intensity. Their results showed that the swirling magnitude, which varies from 0.08 to 0.36, increased with the level of roughness. Darwish (2010) retrieved a turbulent element from the reported "Lubbock-Reese downburst". He calculated the average velocity of the rate of travel over a given length of time (referred to as the "filtering period") and subtracted it from the overall speed. He found that the strongest forces in guyed communication increased with the downburst turbulence element.

Su et al. (2015) assessed these methods for driving the component of mean wind that varies over time. They created an empirical model that took into account the structural fundamental frequency and the time-varying trend of downbursts to determine the likely window sizes. They also suggested ensemble empirical mode decomposition techniques and a discrete wavelet transform with a higher order of Daubechies wavelet.

2.4 topographical influences

The topography speed-up variables for downburst wind speeds have not been thoroughly studied. After conducting a numerical investigation on topographic speed-up factors over a single hill with a slope of 0.25, Selvam and Holmes (1992) came to the conclusion that these factors are typically significantly smaller than those for boundary layer flow. Letchford and Illidge (1998) determined the speed-up factors at a single location for a range of topographic characteristics with slopes between 0.2 and 0.6. They also evaluated the speed-up factors at different distances from the stagnation point (Letchford and Illidge, 1999). They came to the conclusion that as the embankment was positioned farther away from the impact location, the crest speed-up factors reduced and rose with the embankment gradient. Wood et al. (2001) examined the topographic impacts at various separations from the embankment's crest, with the testing surface situated at various separations from the jet outflow. They came to the conclusion that Letchford and Illidge's (1999) suggested speed-up factors were a little bit cautious. Later scholars attempted to incorporate other topological properties by Otsuka (2006) and Mason et al. (2007, 2010). Abd-Elaal et al. (2018) looked into how downburst wind speeds vary over actual terrain. They came to the conclusion that employing 2D topographic data to calculate the average of the undulating terrain slopes across a 500 m horizontal length was insufficient and emphasized the significance of using three-dimensional simulation for terrain topology.

2.5 Downburst line

An outflow producing a line of divergence outward from the line axis is what is referred to as a downburst line (Vermeire et al., 2011b). Approximately one-eighth of all downburst events fall into this category (McCarthy et al., 1982; McCarthy and Wilson, 1986). But compared to a single downburst occurrence, downburst lines pose a worse threat because of their wide surface footprint, which puts more structures at risk simultaneously (Oliver et al., 2000). When Vermeire et al. (2011b) examined downburst lines, they discovered that the wind speed direction and velocity profiles did not match what would be predicted for a single, isolated downburst occurrence. When compared to solitary downburst events, the peak maximum speed in the downburst line has an amplification ratio of up to 1.55, and the destructive surface footprint has grown by up to 70%.

2.6 Drag & Lift coefficients

According to standard wind load regulations, drag and lift coefficients for transmission tower members, conductors, and wires have been calculated for horizontal winds; however, these coefficients did not take into consideration the downburst scenarios when the wind loads are inclined. Using wind tunnel tests, Mara (2007) investigated the drag and lift coefficients for different vertical and horizontal angles of wind projections and computed the coefficients for inclined wind. Afterwards, Mara and Hong (2013) looked into how a single transmission tower responded to changes in wind direction. They came to the conclusion that the tower's capacity curve depends on the direction of the wind.

2.7 Guidelines and gust-front factor techniques

The majority of international standards and codes disregard the forecast of downburst wind loads and do not specify or design for downburst events. One of the standards that takes into account the impact of downburst winds is the Australian/New Zealand Standard (2010) "AS/NZS 7000:2010 Overhead line design," which introduces two straightforward design charts for the horizontal and vertical distribution of horizontal wind speed, ignoring the vertical wind speed. A thorough comparison of the design restrictions set out by international codes, taking into account design wind speeds, wind pressure, conductor forces, tower forces, and gust variables, was provided by Aboshosha et al. (2016). For the suggested horizontal pressure from wind pattern on extended structural systems, the Span Decrease Factor (SRF) is displayed in Fig. 1. The following sources are used to derive this SRF: the Australian/New Zealand Regular "AS/NZS 7000:2010 Overhead line design", the projection for the Lubbock-Reese downdrafts of 2002 from Aboshosha and El Damatty (2013), the estimate for the same from Holmes et al. (2008), and the recommended value for a synoptic wind. The difference between the synoptic wind profile and the recommended profiles for downburst occurrences is seen by this comparison. However, SRF is not well described. The time records of the gusts from the Lubbock-Reese downdraft were squared by Holmes et al. (2008) so they were equal to wind pressures to attempt to predict the wind loads over various span sizes. the SRF is the ratio of the peak conductor reaction, which takes into account the wind field's spatial correlations, to the comparable value calculated under the full correlation assumption. In contrast, ASCE-74 (2010) does not specifically address downburst events; instead, it refers to the use of a Gust-Front Factor (GFF) for extreme wind loadings or tornado-type narrow-front loading. However, the GFF takes terrain exposure and conductor height variation into account. A gust-front factor (GFF) was created by Kwon and Kareem (2009) to take into consideration changes in load effects in gust-front winds. The kinematic and dynamic aspects of gust-front-induced wind effects on structural systems are summarized in this GFF. They suggested using this factor as a treatment for conventional synoptic wind in combination with the currently in place design requirements. They did point out that this study might be expanded to include more intricate structures, but it was restricted to building structures.

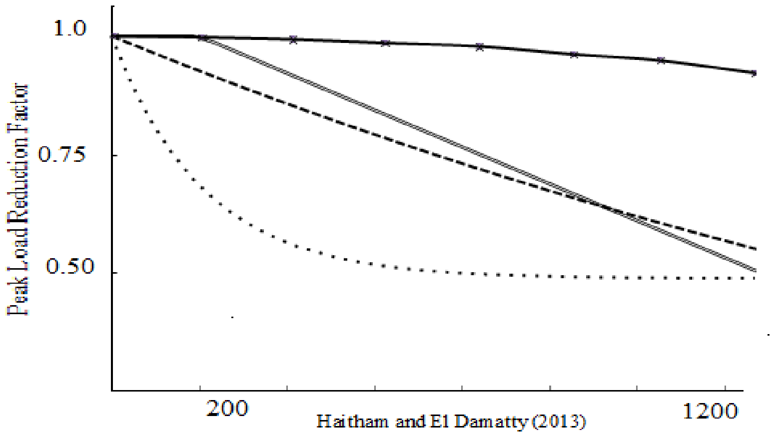


Figure- 1 Factor of span reduction for maximum pressures.

2.8. Synopsis of downburst wind modelling and suggestions for additional study

Downburst wind speeds have been generated and simulated using analytical, computational, and experimental methods. To verify these findings in the temporal and spatial domains, there is, however, insufficient data for large-scale events. The majority of research examined the downburst as an axisymmetric occurrence, with less attention paid to the parent cloud's velocity and sub cloud wind shear. On prolonged structures like TLS, however, the resulting downburst wind profile is altered by the cloud and sub cloud motion. Researchers have validated the scale dependency of downburst simulation models, and this challenge impacts the simulation outcomes. The computational cost of large-scale numerical simulation is substantial. It is important to take into account the variations in downburst flow profiles at different simulation scales, especially since the majority of structural systems and primary surface characteristics like terrain categories and surface roughness are situated in a very small height range of less than D/50, where D is the downburst diameter.

More research is still required to determine how topography affects downburst wind speed and the accompanying speed-up factors. Most studies have only looked at 2D topographic features and have not mimicked complex topology, which calls for 3D modelling of various topographic variables. Furthermore, the variations in the vertical component of downburst wind speed above various topographic features have not been taken into consideration.

To create a GFF or SRF for downburst wind events, more investigation is needed. First, the span reduction factor needs to be precisely defined. The critical loading scenarios that result in maximum forces in various TLS elements should be reflected in this formulation. Then, as these occurrences can represent the true coherence in downburst winds, fully documented field events—like the ones studied by Holmes et al. (2008) and Stengel and Thiele (2017)—should be used. The generated GFF or SRF may take into account changes in conductor height and exposure to the topography, as well as summarize the kinematic and dynamic aspects of wind effects on transmission line systems. Last but not least, it is generally expected that climate change would result in bigger and more frequent extreme weather phenomena, such as downbursts (Brook, 2013). Strong winds that have wreaked devastation throughout Europe, America, the Caribbean, and Australia in the past ten years appear to have validated these notions. Consequently, it is imperative to examine the likelihood of alterations to several downburst parameters, including event frequency, wind intensity, and downburst size, that may be anticipated as a result of climate change.

3. AN EXAMINATION OF TLS'S STRUCTURE UNDER WIND STRESSES

3.1. TLS modelling during a downburst

Different models, restricted to isolated towers, were developed by Savory et al. (2001) for transmission towers under tornadoes and downbursts. But the uneven dispersion of wind loads brought forth by these kinds of incidents emphasizes how crucial it is to examine complete structural systems rather than individual towers. A finite element model for full guyed TLS under downburst wind loads was introduced by Shehata et al. (2005). Later, Shehata and El Damatty (2007) investigated how the development of forces in transmission tower members was influenced by downburst features, such as jet velocity, position, and diameter. Darwish et al. (2010) examined guyed TLS and included the impact of turbulent speed to downburst mean speed. Next, Darwish (2010) examined a transmission line that supported itself during stationary downbursts. Afterwards, he included the parent storm translation speed and looked at the transmission line system during downburst loads. Nevertheless, the ongoing shift of the downburst center with respect to the parent storm translation speed was not taken into account in our study.

A method for calculating the responses of conductors subjected to downburst loads in both the longitudinal and transverse directions was devised by Aboshosha and El Damatty (2015). Elawady and El Damatty (2016) described a method to calculate the pretension force of a crucial conductor under downburst loads while taking various geometric and material aspects influencing the conductors' behavior into account. At the Wind EEE dome, Elawady et al. (2017) carried out an aero-elastic scaled experimental test of a multi-spanned transmission line. Different models have been created for conductors and ground wires.
A three-node iso parametric finite element model has been used to represent them (Desai et al., 1995). Some have modeled them as a continuous curving beam in two dimensions, with ten consistent elements for each cable span (Shehata et al., 2005). The cables were modelled as a collection of geometrically non-linear and mechanically linear 2-joint truss elements by Bartoli et al. (2006) and Cluni et al. (2008), who also conducted experimental verification of the model. Yang and Hong (2016) used 30 two-node link components per span to model the conductors and ground wires as link elements. In scaled experimental testing, Elawady et al. (2017) simulated the scaled bundle using airplane cables.

According to Shehata et al. (2005), two perpendicular linear springs can be used to mimic the insulator strings since they function as a three-dimensional pendulum. Others, however, (Gani and L´egeron, 2010) treated the insulators as six truss elements. The swing angle was unrestricted in these models, and the insulators could rotate freely. According to Duranona and Cataldo (2009), downbursts may produce strong winds that result in high sway angles, which may draw the conductors nearer to the towers. According to Battista et al. (2003), while analysing wind flow and TLS interactive dynamic behaviour and reaction, insulators are the most crucial part of the system.

3.2. Transmission tower joint slippage and linear and non-linear analysis

One of the hardest types of lattice structure systems to analyse are transmission towers. There are notable discrepancies between the forces in members determined by full-scale testing and those derived from linear analysis, and it is not possible to forecast the behaviour of transmission towers under complicated loads using basic methods (Albermani and Kitipornchai, 1992). After researching the non-linear behaviour of lattice towers, Prasad Rao and Kalyanaraman (2001) came to the conclusion that design techniques based on linear analyses do not match test outcomes.

Prasad Rao et al. (2010) looked into a number of early failure scenarios that occurred during transmission tower full-scale testing. They discovered that non-linear analysis produced results that were more accurate than those from linear analysis, and that utilizing non-linear analysis made it possible to anticipate the transmission tower's likely capacity. In order to simulate tower members, Albermani et al. (2009) presented a non-linear analytical process that uses beam-column and truss elements to predict the failure of transmission towers. In order to determine which modelling process best reflected the guyed transmission towers, Oliveira et al. (2007) looked into the towers using three distinct approaches. In the first modelling method, truss elements were utilized; in the second, beam elements with stiff connections were employed; in the third, beams were used for the major legs of the tower and truss elements for the bracing components. They used both dynamic and static linear and non-linear analysis to assess the three modelling techniques. It was suggested to use truss elements for bracing components and beam elements for primary members. In their theoretical investigation of the impact of bolt slippage on lattice tower deflection and ultimate capacity, Kitipornchai et al. (1994) found that bolt slippage significantly affects deflection but has no influence on ultimate strength. Ungkurapinan et al. (2003) conducted an experimental investigation of a number of variables, including the number of bolts, construction clearance, and load applied, that affect joint slippage. They created a mathematical formula to describe the connection between applied load and joint slippage. The effects of joint modelling in lattice transmission towers were investigated by Jiang et al. (2011). They found that structural analysis models that disregarded joint slippage effects and eccentricities are only approximations of the global response of lattice towers observed in full-scale tests. They conducted their research experimentally and validated their findings statistically. They claimed that depending on the loading scenario, the impact of joint slippage on the final capacity varies. When it comes to torsional loading, the ultimate capacity is not much affected, but when it comes to flexural loading, it is around 15% lower than in models where joint slippage is not taken into account.

3.3. Analysis of the transmission line system, both static and dynamic

It is important to distinguish between the frequencies of the turbulent and non-turbulent downburst mean wind components in order to properly comprehend the dynamic analysis of transmission line systems at downburst wind speeds. Unlike synoptic wind loads, downburst wind loads produce extremely strong winds that quickly change in direction and speed. Kim and Hangan (2007) found that the downburst frequency is 0.01 Hz (T = 100 s) in the opposite translation and 0.025 Hz (T = 40 s) in the translation side after analyzing a full-scale downburst event and taking the translation velocity of the downburst into consideration. The turbulence for a full-scale downburst was studied by Holmes et al. (2008), who discovered that the frequency range of the peaks was 0.005–0.4 Hz. Darwish et al. (2010) have studied the turbulence component for the same full size downburst event. They discovered that frequencies lower than 0.01 Hz are where the peak power spectrum occurs.

Yasui et al. (1999) and Battista et al. (2003) have reported that the natural frequencies of self-supporting transmission towers were 1.28 Hz and 1.35 Hz, respectively, with regard to the frequencies of the towers and conductors. The natural frequencies of guyed transmission towers and conductors were calculated by Shehata et al. (2005) to be 1.73 Hz and 0.12 Hz, respectively.

The minimum frequency determined for conductors (0.12 Hz), guyed transmission towers (1.73 Hz), and self-supporting towers (1.28 Hz) differs significantly from the mean wind frequency of 0.025 Hz. Dynamic analysis will therefore not be required when examining transmission tower systems under down-burst mean wind components. The impact of the turbulent downburst component is still not entirely clear, though. Given the significant aerodynamic damping, some academics argue that quasi-static analysis suffices, while others emphasize the value of dynamic analysis.

3.4. How conductor bundling affects

Conductor bundles are frequently used in the construction of long, high-voltage TLS. Transmission line studies have seldom incorporated conductor bundling because wind activities on conductor bundles produce vibrations and aerodynamic coefficients that are different from those on single conductors. Cooper (1973) determined the aero-dynamic coefficients for a bundle of two conductors using experimental data. Next, a bundle of conductors' aerodynamic and aeroelastic properties were numerically investigated by Braun and Awruch (2005) (Fig. 2).

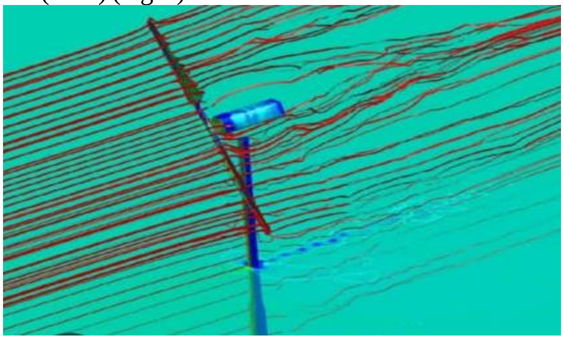


Figure-2 wind streamline

The interplay between conductor bundles and their structure was studied by Riera and Oliveira (2010). Based on the allowable mobility of the bundle, they categorized the models into four groups: completely interacting bundle, flexible interacting bundle, stiff bundle, and flexible bundle. Notwithstanding their disregard for the boundary conditions at the span end, they were able to establish a dynamic response for a normal span under wind loads.

3.5 Critical parameters of a downburst

They considered the three optimization parameters (D, r/D, and θ) to be independent variables: r/D ratio (0.0–2.2), jet diameter (D) (500–2000 m), and θ (00–900 m). In order to have around 100 random instances in the population, they divided each parameter range into multiple divisions. To construct the generations and determine the key microburst parameters for every member in the trans-mission tower, they used genetic algorithms with grid mutation. According to Darwish (2010), the impacts of changing θ and r/D were more important than changing D. El Damatty and Elawady (2018) subsequently added transmission line characteristics, including conductor qualities, tower kinds, spans, and heights, to the previous analysis.

3.6. Transmission tower failure analysis

Failure analysis plays a crucial role in locating the critical zone or vital members within transmission towers. It also helps determine the necessary reinforcements in the event that towers require upgrading, as well as how to arrange them within the TLS. A half-scaled structure test was developed by Moon et al. (2009) to assess the transmission tower failure scenario. They came to the conclusion that expanding the major members or adding stiffeners to the weak joints was required, and that adding more bracing might not increase the transmission tower's strength or stiffness.

3.7. Summary of TLS modelling and suggestions for further study

It is recommended in the prior evaluation that an analysis be created that gathers the findings from each of these investigations. It is necessary to create finite element models, add joint slippage, and model the bracing components as truss elements, beam elements, and the main tower leg members as beam elements. as the primary types of insulators have not yet been examined (Fig. 3b).

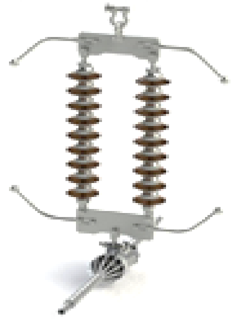


Figure 3 (a)

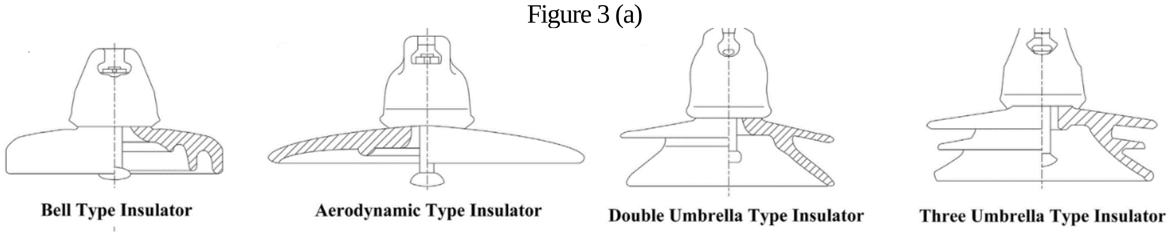


Figure 3 (b)

The path of a TLS is separated into straight portions in order to plan its construction. “Suspension towers” are applied among the sections, and tension towers are located at each end of the sections. Consequently, the model has to account for tension towers, and research has to be done on how these two kinds of towers interact.

With the exception of one study by Darwish (2010), transitory downbursts were not included in the prior research. Although disregarded, Darwish (2010) included the “translation speed” as a vector “summation for downburst speeds”. According to Holmes (2001), the translation speed can be one-third that of the downburst. Based on multiple references, Kwon & Kar-eem (2009) deduced that the “storm translation speed” is around “10–20 m/s”. This speed is important and needs to be included to the downburst event-produced speeds in addition to taking the downburst centroid's movement into account.

It is currently unknown how TLS would behave structurally under tilted “downburst and downburst lines”, and its behaviour under various downburst sizes is not fully understood. Although Shehata and El Damatty (2007) and Shehata et al. (2005) examined the TLS over a broad range of downburst diameters, they disregarded scale dependency and scaled this range from a single downburst event. It might not be sufficient to scale a variety of events from a single downburst event. Lastly, to the best of the authors' knowledge, only a few experimental investigations and no numerical research have been done to analyze the wind-structure interaction of TLS under downburst wind loads.

4. TLS UPGRADE

4.1 Transmission tower and transmission line systems retrofitting

Many older “transmission towers” are incompatible with modern standards, which motivated searchers to look at reinforcing techniques. Old transmission towers can be upgraded using a variety of reinforcing techniques, including the x-brace method, friction type reinforcement, diaphragm bracing system, and leg retrofitting method. In order to modernize outdated lattice towers, “Albermani et al.” (2004) employed a “diaphragm bracing system” at the midpoint of diagonal members. The upgraded samples were put through two load cases: torsional and bending. The results showed that the diagonal compression members' buckling load capability had risen by 156–289%. They came to the conclusion that renovating older “transmission towers with high leg slenderness ratios” is highly successful when a diaphragm is used.

Park et al. (2007) improved the transmission towers' ability to withstand wind loads and reduced the force acting on the primary structural parts by using friction-type slotted connections. According to their investigation of two units from the “friction-type reinforcement” can strengthen the main axially laden legs of the transmission tower and increase its capacity for dissipating energy (Park et al., 2009). To lessen real-world installation issues including corrosion “resistance at the sliding” interface and variance in friction force due to cyclic stress, they made certain changes to slotted bolted connections. They suggested creating a new closed kind of friction damper and utilizing stainless steel plates for slotted contacts with ground surfaces. There hasn't been much research done on the x-brace reinforcing technique. A brief numerical comparison of friction-type reinforcing methods and x-brace reinforcement methods was carried out by Park et al. (2007). They discovered that the braced members hold very little of the strain and that the tower legs, with their cantilever motion, bear the majority of the stresses. After comparing these two approaches, Tongkasame et al. (2007) found that the slenderness ratio of the original member determines how effective each method is, and that members with a high slenderness ratio of $\Im/i > 100$ benefit most from the x-brace method. According to Alminhana et al. (2016), strong winds are the primary cause of cascading failure incidents. From a large-scale perspective, cascading failures that set off a lengthy chain of TLS failures result in costly societal and economic consequences. The various approaches to mitigating cascading failures were introduced in “CIGRE´ Technical Brochure No. 515” (2012). These included the installation of anti-cascading towers at predetermined “intervals, load reduction and control devices”, load-limiting cross arms, and control sliding clamps. But the majority of these methods are more useful in the early phases of design than as alternatives for retrofitting an already-existing TLS.

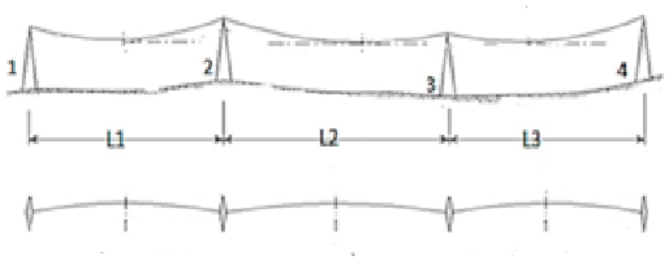


Figure-4 weight & wind Span

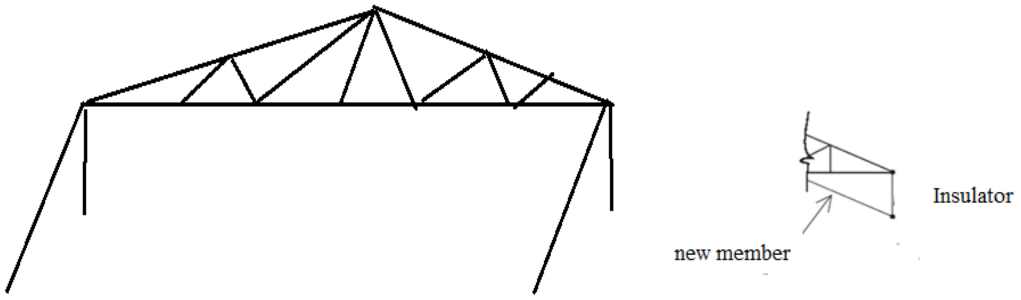
4.2. Synopsis and suggestions for retrofitting

For reinforcement, the following scenarios are recommended:

1. Introducing reinforcement solely for critical members in towers, which may include redundant members, primary members, bracing members, or critical joints.
2. Presenting comprehensive systems of reinforcement, such as the use of leg reinforcement, x-brace-style techniques, diagonal bracing, or a combination of two techniques.
3. Strengthening with solid round steel components

Then, both the general kinds of wind loads and downburst wind loads should be considered while evaluating these reinforcement techniques. It is important to take into account their efficiency, ease of construction, affordability, and best possible distribution of reinforcement throughout the TLS.In addition to employing U-bolts in every situation, Kumalasari et al. (2005) looked at the reinforcement of solid round steel members by adding one or two split pipes, both with and without end welds. Compression strength was raised by 30% by using two split pipes without end welds, and by 60% if the end was welded. This indicates that the efficacy of one split pipe with end welds is comparable to that of They advised against utilizing end welds and suggested using two split pipes instead because field welding is costly and dangerous.

Using U-bolts in conjunction with adhesive connections rather than welded ones is an additional option. Although adhesive connections exhibit more Their prior restrictions might be improved, nevertheless, if the glue has been used in “conjunction with a bolted connection”. Instead than focusing on strengthening every tower in TLS, the authors advise investigating novel methods and strategies. For instance, the wind load on transmission towers. The “horizontal distance between” the converters' lowest points is known as the weight in a TLS, if certain towers see a decrease in wind loads, the remaining towers will experience an increase. In this instance, additional reinforcement will be needed for the second group of towers, whereas the first group won't need any. Controlling the insulators' rotation angle (Fig. 5a) will alter how wind loads are distributed throughout the nearby towers. This might be accomplished by decreasing the swing angle of the insulator chains and providing some fixation by the addition of elastic elements (Fig. 5b). This modification ought to be implemented for 50% of TLS towers, namely the unusual ones.



(a) (b)

Figure-5 Insulator swing angle

4.3 Optimal design of TLS

various stages of richment are involved in the optimal design of TLS, starting “with the selection of” voltage and conductor specification and concluding the specifics of the tower component design (Ghannoum and Yaacoub, 1989). By examining the tower placement in one of their straight sections, Ranyard and Wren (1967) created a method to determine the ideal tower configuration in TLS. A number of restrictions were placed on the process: “towers had to be spaced” according to a single span restriction conductors had to be kept at least a certain distance from any point on the land, the total “length of the adjacent spans” could not exceed upto largest, and each tower could only support a minimum of “35% of the combined load” of the two spans it carried.

White (1993) investigated conductor optimization, the quantity of steel required for conductor reinforcement, and the alloying option. He was able to reduce the total weight of support steel by 30%, but he omitted talking about how much alloying and steel reinforcing would have cost. Shea and Smith (2006) optimized shape and topology to improve transmission tower design. By optimizing the current towers' joint locations, topology, size of the member sections, and tower envelope, they were able to lower the structural mass of the towers. In addition to presenting a layer combination optimization technique to produce novel configurations, Guo and Li (2011) advanced structural topology optimization techniques.

However, as the tower foundations and conductors represent the majority of the total cost of TLS, tower optimizations based solely on lowest weight suffer greatly (Ghannoum and Yaacoub, 1989). They suggested optimization techniques that integrated the tower and foundation costs.

In his 2010 study, Darwish examined two guyed towers, measuring 44 and 55 meters, respectively. He discovered that altering the guy arrangement or raising the height had no impact on the general behaviour of the tower parts exposed to “downbursts”. According to Dagher and Lu's (1993) stability study of exchange lines exposed to strong thunderstorms and local winds, the likelihood of a transmission line failure is directly correlated with its length. They asked about the ideal distance between different types of tension towers and the ideal length for the transmission line. Subsequently, “El Damatty and Elawady” (2018) looked into the effects of modernizing three distinct kinds of “guyed tower systems” with comparable spans. It was determined that the necessary increase in tower weight as a result of downburst loads in comparison to the original towers was 14%, 23%, and 3%. This may indicate the important impacts of the transmission line characteristics, such as tower height, conductor cross arm width, “number of conductors”, conductor diameters, “insulator length”, etc. Unfortunately, the search of the people “that support the towers” was left out of this study, despite the fact that a significant portion of the forces travel through the guys to the ground supports.

5.CONCLUSION

The large-scale wind events are symmetrical and consistent, while the downburst wind speeds are different. The four dimensions of downburst wind speed variation are r, θ, h, and t. The radial distance from the downburst centre is represented by r, the height above the ground is represented by h, the angular direction is effective for asymmetrical downburst events, and t represents the time. Apart from the fluctuations in the four dimensions, downburst wind flows are distinguished by swift changes in time, a highly correlated wind, high wind speeds at extremely low altitudes, vorticity and negative buoyancy, and the fact that events are confined to a specific area both in space and time.

As a result, unlike regular boundary layer wind flows, downbursts cause uneven and the majority of design guidelines do not include enough details about these occurrences. It is possible to draw the following important conclusions from this review:

- Different methods, including experimental, numerical, and analytical methods, have been used to simulate downburst wind loads. Nevertheless, due to the localized character of downburst events, full-scale data is difficult to gather, and these models have not yet been satisfactorily tested or calibrated against it.
- Although TLS throughout downburst wind speeds has been studied in earlier research, it has primarily been limited to immobile downburst occurrences. Travelling downbursts, nevertheless could be the primary wind spread on a lengthy structure, such as an electric power s/m, due to the ahead or backward gaps in horizontal movement of downburst wind generated by the primary storm translator speed.
- The study brought to light a number of aspects that need to be taken into account when modeling TLS, such as conductor bundles, a thorough insulator model that takes the swing angle limit into account, “cable-structure interaction”, and “joint slippage effects”.
- Numerous approaches for reinforcing have been introduced, and new developments and applications have been proposed. Additionally, a number of enhancements have been suggested.

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