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Impact Analysis of Wind Farms on Air Traffic Control Radar

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ABSTRACT

These days, wind vitality use gets to be gigantic which prompts an increment in number of wind turbine establishments. Because of these wind turbines, the electromagnetic waves get impedance and are scattered which brings about the loss of correspondence. In this paper, the unfriendly impacts of wind farms on radar framework is displayed and discussed for Air Traffic Control (ATC) Radar. Coimbatore domestic (ATC) radar working in S-band recurrence gets influenced by wind farms located in Palakkad gap area. Demonstrating of the wind turbines and estimation of Radar Cross-Section (RCS) is done utilizing high frequency EM solver viz., XGtd tool. The investigation of RCS dispersing plot, examination of improved RCS and air traffic issues revels that the wind farms exhibit in viewable pathway and those near to radar influences the framework and results in loss of information which leads to poor air traffic monitoring.

KEY WORDS: Air Traffic Control, Radar, Radar Cross Section, S-band, Wave Scattering.

1. INTRODUCTION

In present days, wind vitality has turned into one of the critical wellspring of power and installed in colossal numbers all over the world. Because of the vicinity of these wind turbines, radar signs get influenced and its motivation is not satisfied. Vicinity of wind turbines influences the different types of communication and radar systems. The effects due to wind turbines can be given by three noteworthy impacts in particular: Large size of wind turbine, rotational speed compared to airplane and wind farm sizes. Because of these impacts, more quantities of wind farm ventures are postponed, and alleviation strategies are required taking into account the materials utilized, thickness, blade orientation and reliable modeling. Electromagnetic (EM) waves from the radar transmitter get encroached on the extensive structure of wind turbines which brings about dissipating of waves in all headings. Both hypothetical and exploratory studies have been directed to evaluate the effect of wind turbines on different frameworks including climate radar, air traffic control radar, defense radar, and marine radar, also as radio communication and navigation. Two sorts of electromagnetic phenomenology can offer ascent to obstruction impacts: radar clutter and electromagnetic transmission obstruction. Radar clutter emerges from the backscattered signal by large wind turbines and is mainly concerned to radar systems. Due to this Doppler clutter by rotating blades, air traffic and weather radar functions are disturbed. The issue of electromagnetic transmission obstruction is more inconspicuous and accordingly harder to evaluate.

So as to study the dispersing of EM waves, high frequency solver equipped for assessing Radar Cross-Section (RCS) of electrically huge item is required. The XGtd software tool is a high frequency solver capable of calculating the Monostatic and Bistatic radar cross section of electrically large objects. It is a Full 3D Ray-Tracing Solver, based on Uniform Theory of Diffraction (UTD) with corrections for finite conductivity materials, including thin coatings and an ideal solver for electrically large platform models or scenarios. It also computes far zone radiation patterns with effects of scattering from electrically-large platforms and nearby objects. In this paper the impact of wind farms located in Palakkad gap region on Coimbatore air traffic control radar (11.0267° N, 77.0417° E) is analyzed using XGtd software tool and the resultant radar cross sections of wind turbines and aircrafts are studied. Three types of aircrafts are used for RCS study viz., Emirates sky cargo Boeing 777-200F, Airbus A320neo and Boeing 737-8GJ Spice Jet. The maximum scattering plot of wind turbines is compared with RCS of aircraft and its corresponding overlap angles are obtained from the resultant RCS plot.

Wind turbine distribution and radar: The area considered for examination and study is the Palakkad crevice area (10°56' N, 77°3' E to 10°32' N, 77°36' E), which lies in Western Ghats of India between the states of Tamilnadu and Kerala with a normal height of 140 meters. It burrows the wind blowing with a yearly speed of 18-22 km/hr. from the west on to locale in Tamilnadu viz., Coimbatore and Tirupur making the area one of the real wind force creating districts in India. Vast number of wind turbines are seen in and around Udumalaipettai and Kadathur of Tamilnadu. The vicinity of wind turbine is in locale of Coimbatore and Tirupur impacts and is the reason for obstruction to the radar frameworks display in and around 5-35 km. The Coimbatore (air traffic control) radar (11.0267° N, 77.0417° E) present close to these wind farms gets interference and signals are scattered to large extent. Due to this scattering of signals, entire air traffic monitoring system of Coimbatore radar is disturbed and results in loss of communication. All the wind turbines present in regions of Coimbatore and Tirupur districts are mapped using Google earth. In order to analyze the impact of wind turbines on radar, entire study area is made into equal grid using GE path tool. Fig. 1 shows the Google earth screen shot of mapped wind turbines (yellow push pins) with Coimbatore radar (green push pin). For the RCS analysis, the wind turbines located in and around 5-30 km distance from Coimbatore radar are considered. From each grid wind turbine numbers are obtained statistically with respect to distance from Coimbatore radar and entire distribution of wind turbine in histogram form is shown in Fig. 2.

Figure.1.Mapped wind turbines with grids and Coimbatore Radar

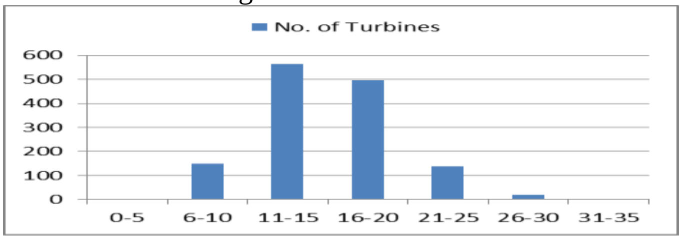

Figure.2.Wind turbine density distribution in and around 5-30 km distance from Coimbatore radar

Histogram plot shows that at a distance of 11-15 km more number of wind turbines is present which can influence radar signals to greater extent. In following sections the modeling of wind turbines using XGtd software tool and RCS estimation are discussed.

Modeling of Electrically Large Structures: XGtd software tool by Remcom, is a full 3D Ray-Tracing solver, based on Uniform Theory of Diffraction (UTD) with Shoot and Bounce Ray method (SBR). The SBR system follows the beam ways through geometry without respect to the area of particular field focuses. Beams are initially followed from the source focuses, with the beams reflecting specularly from the features of the different focuses in a given study space. The beams that hit aspects are reflected specularly and keep on being followed up to the most extreme number of reflections, or when the beams hit the study region limit. The electric field of the beam way is discovered in view of associations. The yield amounts, for example, time of arrival, far-zone reception, drive reaction, resultant power, and so on, are computed by joining all the beams coming to the beneficiary point. Modeling of wind turbines and RCS estimation can be done using XGtd software tool which also provides facility for utilizing different materials and thicknesses for turbine blades.

Since XGtd tool is a high frequency solver, it requires high performance device for processing and estimation of RCS. Intel (R) Core (TM) i7-4790S CPU @ 3.20GHz, Installed memory (RAM) of 8.00 GB with 64-bit Windows 7 Professional Operating System is used for this study. Due to this constrain calculation of RCS for more number of wind turbines consumes enormous time and memory. Hence, maximum of 15 wind turbines are considered for calculation of RCS. In order to analyze the RCS of wind turbines in XGtd tool, its 3D model with planar facets is needed. So, Enercon E66 wind turbine model accessible in Google's 3D warehouse is utilized for estimation of RCS. This model is in .skp or .dat format. To use in XGtd tool, .dxf or .sat arrangement model is necessary. Thus, Enercon E66 is imported to CAD or Sketchup tool for the transformation into suitable configuration. After transformation, every parts of wind turbine are imported into XGtd software which on whole made out of 1,100 facets for single turbine structure.

After importing the entire model into XGtd tool, transmitters, receivers, study area, antennas, waveform, materials and required outputs are selected. From the reflection coefficient of materials study, fiberglass with 0.076m thickness is used as turbine blade material and Perfect Electric Conductor (PEC) as tower material. The waveform frequency is chosen to be 4 GHz (S-band) with sinusoidal nature which is same as that of Coimbatore radar. Likewise, by varying the geographical location of wind turbines upto maximum of 15 wind turbines are imported into XGtd tool. Hence, 15 XGtd models with wind turbines varying from single turbine to 15 turbines will be available for RCS estimation. Fig. 3 and Fig. 4 show the wind turbine XGtd models for 2 wind turbines and 14 wind turbines respectively with plane wave transmitter resembling Coimbatore radar.

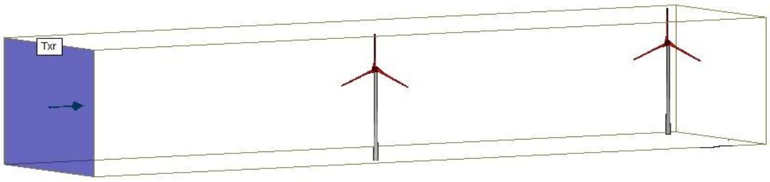

Fig.3.XGtd model for 2 wind turbines

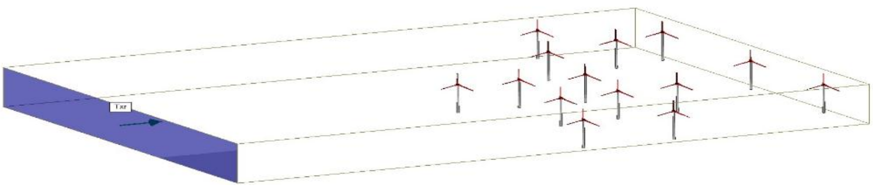

Fig. 4. XGtd model for 14 wind turbines

Estimation of Radar Cross Section: The Radar cross-section of wind turbines is obtained from XGtd tool by selecting the far zone radiation RCS as output type. After modeling the wind turbines and selecting appropriate output, entire setup is processed by XGtd tool. The Radar Cross Section (σ) is defined as, the area intercepting that amount of power which, when scattered isotropically, produces at the receiver a density which is equal to that scattered by the actual target. Mathematically, RCS is given by

$$\sigma_{\mu v} = \lim_{r \to \infty} \left[4\pi r^2 \frac{\left| E_s \cdot \hat{e}_\mu \right|^2}{\left| E_i \cdot \hat{e}_v \right|^2} \right]$$

Where $\hat{e}_\mu$ and $\hat{e}_v$ are the unit polarization vector of the scattered field and incident field respectively, r is the observation distance from the target, E_S is the scattered electric field vector, E_i is the field incident at the target vector, the subscripts μ and v can be either the linear polarization components θ, ϕ or circular polarization components. Once the process of calculation is completed by XGtd, RCS scattering plot in polar form is obtained in the output window. For each XGtd model a unique RCS scattering plot is obtained which yields 15 RCS scattering plots. These plots correspond to wind turbines present in and around 0-30 km distance from Coimbatore Radar. The working frequency is 4 GHz (S-band) with sinusoidal waveform. From the resultant RCS plots, statistical analysis is done for finding the maximum signal scattering wind turbine distribution. In the RCS scattering plot, 0° degree represents the upward direction, 90° is the incoming plane wave direction and is also the angle of backscatter, 180° represents the direction of forward scatter and 270° is towards the ground. From the statistical analysis of RCS above 10 dBsm for 15 wind turbine models, it is evident that XGtd model with 12 wind turbine distribution contributes to enormous scattering (39 dBsm) of radar signals. Fig. 5 shows the RCS scattering plot for 12 wind turbines in which the scattering is enormous when compared to other wind turbine distributions.

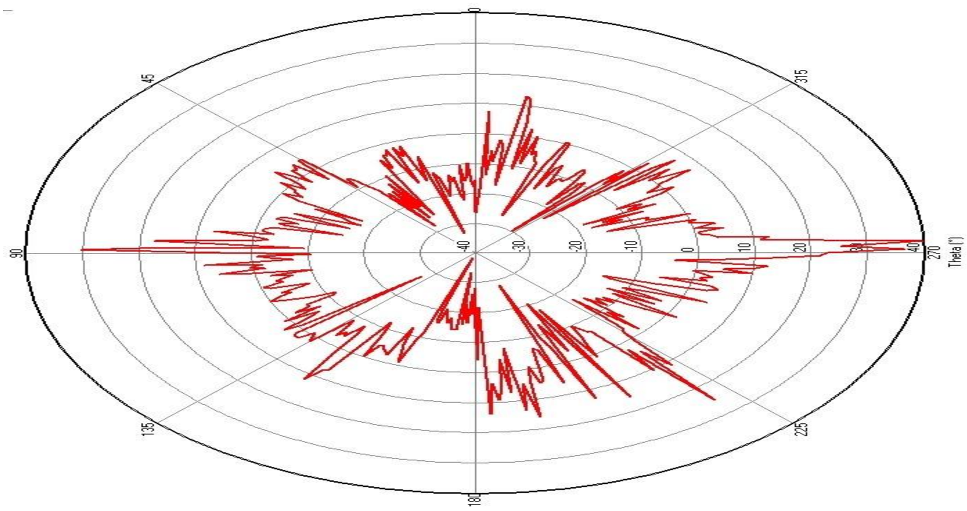

Fig. 5. RCS Scattering plot for 12 wind turbines

The scattering of signals and number of wind turbines are proportional to each other emphasizing as number of wind turbines located near to radar increases, the scattering of signals also get enormous which leads to loss of communication.

Comparison of Wind Turbine and Aircraft RCS: The scattering and interference of signals due to wind turbines present near to air traffic control radar makes its operation poorer i.e., the communication of aircraft with ground station is lost which leads to aircraft accidents, loss of flying path, improper landing, etc. In order to study the effects of wind turbine on Coimbatore ATC radar, three aircrafts (Emirates sky cargo Boeing 777-200F, Airbus A320neo and Boeing 737-8GJ Spice Jet) RCS are compared with RCS of maximum scattering wind turbines obtained earlier. First, all the three aircrafts 3D models are obtained from Google's warehouse and imported into CAD or Sketchup tool for converting .skp file format to .dxf format. Similar to wind turbine modeling, each aircrafts entire planar structure with facets is imported into XGtd software tool which is then scaled down to real scenario and placed exactly at the distance of wind turbine from Coimbatore radar. Transmitters, receivers, study area, antennas, waveforms and required outputs are selected as same as in case of wind turbines. Fig. 6 shows the XGtd model of Emirates sky cargo Boeing 777-200F with transmitters operating at a frequency of 4 GHz (S-band).

Fig. 6. XGtd model of Emirates sky cargo Boeing 777-200F

RCS scattering plots of all the three aircraft is obtained from XGtd tool, and statistical analysis is done for each aircrafts RCS. From the study it is evident that RCS scattering of Emirates sky cargo Boeing 777-200F aircraft is larger. Hence, the RCS of 12 wind turbines is merged with RCS of larger scattering aircraft and overlapping angles are identified. The resultant plot shows that at the regions of overlapping angles, the scattering of radar signals is enormous and affects the Coimbatore radar operation i.e., if the Emirates sky cargo Boeing 777-200F aircraft is flying at RCS overlapping angles, due to scattering of signals there is loss of communication and radar is unable to detect the aircraft which leads to poor monitoring of air traffic. Fig. 7 shows the merged RCS scattering plot of 12 wind turbines and Emirates sky cargo Boeing 777-200F. Table I displays the RCS overlapping angles. Thus from the merged RCS analysis, it is observed that if an aircraft is aviated or placed in the overlap angles of wind turbines, the aircraft is unnoticeable and its communication with Coimbatore radar is lost which in turn leads to false notifications and alarms, improper landing, air traffic issues and so on.

Table.1.RCS Overlap angles

Overlap Angles (degrees)	RCS Values (dBsm)
38	16
305	12
310	15
320	16
325	16
333	10
335	40

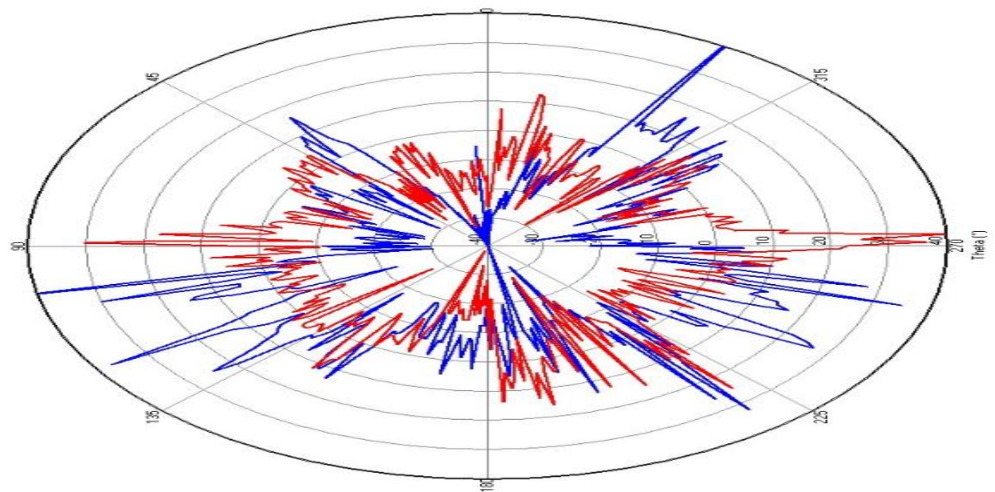

Fig. 7. Merged RCS of wind turbine and Emirates sky cargo Boeing 777-200F

2. CONCLUSIONS

Wind farms constructed in the way of radar signs; influence the radar framework execution because of impedance and scrambling of signals due to clutters produced by wind turbines. The study exhibited here is noteworthy to comprehend the unfavorable impacts of wind turbine on radar signal returns. In this paper, XGtd tool is used, through which reflection coefficient of materials and RCS computation for electrically expansive wind turbines exhibit in locale of Coimbatore radar are done. The correlation investigation of RCS for airplane and wind turbines results the issues confronted by flying framework and Coimbatore air traffic control radar. Thus emphasizing the impact of wind farms on air traffic radar the suggestion is that, it is safer not to build wind farms in line of sight or very close to radar systems and other communication networks which leads to loss of information and communication.

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