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A Security Analysis Method for Remote Tower Application at Feeder Airport

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Abstract: In recent years, the building of the conventional airport tower is usually difficult and costly because of the complicated terrain in remote areas. Moreover, at feeder airport is facing with the problem of controllers shortage. It leads that the remote tower technology has been rapidly developed. The remote tower uses a panoramic display instead of an external view to provide remote air traffic control services. It is necessary to evaluate the satisfaction of safety requirements before the remote tower is put into operation. In this paper, the overall framework of the remote tower is firstly constructed. Secondly, a series of hazard sources are identified and a risk analysis assessment method is proposed in which the risk possibility/severity matrix is carried out to get the outputs. Finally, the responding releasing method are proposed based on the results of the mentioned risk analysis. The results of this work provide a theoretical basis for the implementation of remote tower constrained with the regulation of CAAC.

Keywords: remote tower, hazard source identification, risk management

1. Introduction

1.1. Research Background and Purpose

In recent years, feeder airports are growing fast in China due to its rapid development in civil aviation. However, there are complex terrains in some remote areas with only a small number of daily flights. The building of the conventional tower is usually difficult and costly, coupled with the large gap of air traffic controllers at present. Therefore, the Civil Aviation Administration of China introduced the remote tower technology and vigorously promoted its operation. The paradigm of remote tower operation will allow air traffic services (ATS) be delivered remotely (by using a panoramic display) without direct observation from a local tower. As a new technology, whether the remote tower can meet the relevant security requirements determines whether it can finally be put into operation.

1.2. The Current Status of Foreign Research

Currently, there are three international companies that study remote tower technology, namely Searidge Technologies, Saab and Feikun. They work with different airports around the world to test the operation and implementation of remote towers. ART has embedded existing testing facilities of Sweden for tower remote operation at Sturup airport in Malmo. The focus is on traffic and situational awareness of the tower controller, using remote cameras and projection systems for tower safety operations to replace direct visibility into the airport and its traffic. The validation results provide valuable information for further development and operational applications even outside the scope of remote tower applications [1].

On November 4, 2014, the remote tower developed by Saab in partnership with LFV, a Swedish air traffic service provider, has been granted final operating permits by the Swedish Transport Authority. The remote

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tower centre in Sunzwar can remotely operate Ensherzvik Airport, making Ensherzwik airport the first airport in the world to implement off-site air traffic control.

In 2016, tower control services at Sunzwar airport were also transferred to this remote control centre.

In November 2017, the first successful test of a remote tower controlling multiple airports was conducted in Brunswick.

On April 22, 2018, Saab Digital Air Traffic Solutions (SDATS), will install and operate digital towers for the Scandinavian Mountains airport under construction in Slen. The new airport is scheduled to put into operation between 2019 and 2020.The installation of the remote tower will enable the airport to manage and operate flexible digital tower services from a central location.

The EU's "Single Sky Europe" project launched and introduced the concept of multiple remote tower operation, meaning that air traffic controllers (ATOs) can control multiple airports from remote virtual control centres. Control of multiple airports can be centralized in one virtual hub, allowing the efficient use of ATCO resources [2].

1.3. The Current State of Domestic Research

In China, the technology of remote tower is not yet all-pervading, and there is less research based on the remote tower. At present, Civil Aviation II has developed a set of airport panoramic enhanced monitoring system, as an auxiliary equipment in the traditional control tower. The airport runway, taxiway and apron of 180-360 degrees of panoramic surveillance can be achieved through the 4-8 high-definition video in real-time stitching processing.

By the end of April 2019, Xinjiang airport group remote tower experience operation module completed. The air traffic control department of airport group shall identify, evaluate and control the risks of remote tower operation and function transfer, make plans in personnel allocation and equipment operation, and formulate implementation plans.

On November 4, 2019, after a risk identification and analysis, the assessors developed risk control measures for the hazard sources. The final evaluation of Xinjiang remote tower new technology application pilot work has initially met the conditions for remote tower operation so make it possible to enter into the switching operation stage of remote tower.

2. Remote Tower Functional Frame Structure

2.1. Basic Composition of Remote Virtual Tower

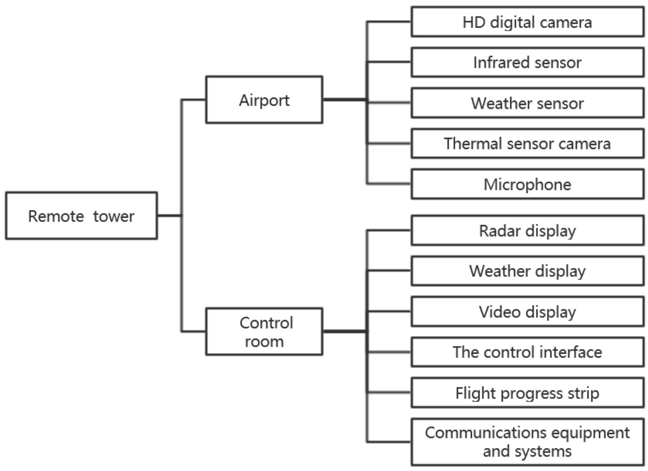

Fig. 1: Basic composition diagram of remote virtual tower

As shown in the Fig. 1, the entire remote virtual tower actually consists of two parts: the airport and the control room. The airport mainly includes HD digital camera, infrared sensor, weather sensor, heat sensor camera, microphone and so on. The control room mainly includes radar display screen, weather display screen, 360-degree airport video display screen (video surveillance system), control interface, flight process strips, five parts with microphone and other related communication equipment and systems (such as image enhancement system) [3].

2.2. External Environment Display (OTW)

OTW is a panoramic display capable of displaying 360° images after multiple cameras and the corresponding display screen are spliced together. OTW needs to be able to display the dynamic information of aircraft, vehicles and personnel in the control area of the currently controlled airport in real time, timely and accurately, as well as the surface conditions, so as to detect foreign matters on the runway in a timely manner, thus ensuring the safety of aircraft taking off and landing.

2.3. Electronic Flight Process Strips System

The electronic flight process strips system displays flight dynamics through the lead automatic reporting link, communicates with the airport electronic process strips server through the dedicated line network, and records relevant instructions of controllers [2].

2.4. Radar Data Processing System (RDP)

A radar data processing system, as the name implies, processes data from the radar. In the remote tower, the radar data processing system can provide the controller with the distance information of the specific aircraft from the runway landing area [4]. In addition, it can be combined with OTW. In the case of low visibility, such as at night and in rainy days, the identification effect of aircraft by video data is not good, and data from radar can be used to assist aircraft identification [5].

2.5. Technical Composition of Remote Tower

The core technology of the remote tower is the real-time video images collected by a number of conventional and infrared cameras arranged in the airport. After comprehensive image processing, the images are projected on a 360° panoramic screen or multiple displays to realize the tower scene reproduction without delay.

Augmented reality technology is the superposition of text information of moving target and weather on the real-time video. Through integrated video tracking and fusion, radar or ADS-B data tracking and fusion, visibility enhancement, remote control based on the point of interest image translation zoom camera and other functions [6].

3. Remote Tower Safety Assessment Analysis

3.1. Remote Control Tower Hazard Consequences Risk Analysis

This paper adopts the method of brainstorming and HAZOP analysis to identify the hazard sources from four aspects of man-machine environment management. According to the hazard identification of remote tower, the possibility, severity and risk index of security risk are determined by using Table. 1&2&3, and the risk index is output into the safety risk tolerance matrix describing the tolerable standard:

Table.1: Security Risk Probability Classification in “Air Traffic Management Safety Assessment”

	EXTREMELY IMPROBABLE	IMPROBABLE	REMOTE	OCCASIONAL	FREQUENT
Quantitative description （per running hour）	$<1\times10^{-9}$	$\geqq 1\times10^{-9}$ $<1\times10^{-7}$	$\geqq 1\times10^{-7}$ $<1\times10^{-5}$	$\geqq 1\times10^{-5}$ $<1\times10^{-3}$	$\geqq 1\times10^{-3}$
Qualitative description （single unit）	Expected to occur<every 100 years	Expected to occur every 10-100 years	Expected to occur about once every year	Expected to occur about once every month	Expected to occur more than once per week
Qualitative description （system scope）	Expected to occur<every 30 years	Expected to occur once every 3 years	Expected to occur once every several months	Expected to occur several times every month	Expected to occur once a day or two

Table.2: Classification of Safety Risk Possibility in "Administrative Measures for Safety Evaluation of Traffic Management in Civil Aviation"

SEVERITY	ICAO SMM	VALUE
CATASTROPHIC	— Equipment destroyed — Multiple deaths	**A**
HAZARDOUS	— A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely — Serious injury — Major equipment damage	**B**
MAJOR	— A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of increase in workload or as a result of conditions impairing their efficiency — Serious incident — Injury to persons	**C**
MINOR	— Nuisance — Operating limitations — Use of emergency procedures — Minor incident	**D**
NEGLIGIBLE	— Few consequences	**E**

Table.3: Risk Matrix

SEVERITY / LIKELIHOOD	**CATASTROPHIC**	**HAZARDOUS**	**MAJOR**	**MINOR**	**NEGLIGIBLE**
FREQUENT	**25**	**20**	**15**	**10**	**5**
OCCASIONAL	**20**	**16**	**12**	**8**	**4**
REMOTE	**15**	**12**	**9**	**6**	**3**
IMPROBABLE	**10**	**8**	**6**	**4**	**2**
EXTREMELY IMPROBABLE	**5**	**4**	**3**	**2**	**1**

ACCEPTABLE	(green)	TOLERABLE	(yellow)	NON-ACCEPTABLE	(red)

(1) Unstable link transmission of operator's dedicated line: the likelihood of its occurrence is frequent (5), the severity of consequence is hazardous (4), and the risk index is (20), which is a non-acceptable high risk. As the control mode can be switched at any time and the airport has the absolute priority in command, the severity is reduced to negligible (1), the risk index is (5), and the final assessment result is an acceptable low risk.

(2) No hot backup on the operator's dedicated line: the failure of frequency of the operator's dedicated line is high, the required time to switch is long and the process is complicated. The likelihood is frequent (5), the severity is hazardous (4), and the risk index is (20), which is a non-acceptable high risk. Due to the fact that the airport tower has the highest priority in command, the severity is reduced to negligible (1), the risk index is (5), and the result is an acceptable low risk.

(3) VHF communication and transport is not stable: VHF voice signal needs to go through multiple communication devices to convert the signal model, the failover cycle is long, the likelihood is occasional (4), the severity is hazardous (4), and the risk index is (16), which is a non-acceptable high risk. As the airport

tower has the highest priority in command, the severity is reduced to negligible (1), the risk index is (4), the result is an acceptable low risk.

(4) The VHF receiving signal of the remote tower has a blind spot: improbable (2), major (3), the risk index (6), the result is a tolerable moderate risk.

(5) Loss of intercom signal: improbable (2), major (3), the risk index (6), the result is a tolerable moderate risk.

(6) ADS-B signal loss: remote (3), negligible (1), the risk index (3), the result is an acceptable low risk.

(7) The content of ADS-B system is missing: remote (3), negligible (1), the risk index (3), the result is an acceptable low risk.

(8) Black screen of apron control system: improbable (2), major (3), the risk index (6), the result is an acceptable moderate risk.

(9) The splicing image of the apron control system is not clear: remote (3), negligible (1), the risk index (3), the result is an acceptable low risk.

(10) No data of self-observation equipment: improbable (2), negligible (1), the risk index (2), the result is an acceptable low risk.

(11) Loss of situational awareness of the controller caused by environmental changes: improbable (2), major (3), the risk index (6), the result is a tolerable moderate risk.

(12) Equipment signal interruption caused by power failure: improbable (2), hazardous (4), the risk index (8), the result is a tolerable moderate risk.

(13) Tower controller incapacitation: extremely improbable (1), catastrophic (5), the risk index (5), the result is an acceptable low risk.

3.2. Remote Tower Risk Mitigation Strategy

The establishment of the risk mitigation strategy mainly focus on whether the risk can be effectively reduced to as low as reasonably practical level (ALARP) or even eliminate the risk. This paper proposes the following mitigation strategies for the above hazard sources accordingly：

(1) When remote control command is implemented, the airport controller monitors the situation of the control command throughout the whole process. In addition, the priority of airport control command is higher than that of remote tower centre; use the civil aviation telecommunication network already installed at the airport as the standby line for the special line; optimize the switch configuration of dedicated line service and set the priority.

(2) According to the network architecture in the remote tower construction scheme, subsequent systems requiring remote transmission are equipped with dual network cards and redundant backup of network communication equipment, so as to realize dual-line hot backup; by opening up the dedicated lines of two operators, the load balancing equipment is increased, and the double-link hot exchange is realized.

(3) Auxiliary communication equipment is added to reduce VHF communication nodes; add VHF remote terminal as backup; add intercoms as VHF device backup.

(4) If the signal of the aircrew is not received, it shall be directed by the airport controller immediately; try to use a network VHF device; add satellite telephone communication equipment.

(5) Through setting up video communication or other means airport personnel information exchange is strengthened; standardize the terminology when in and out the runway.

(6) By observing and recording for a long time, set out the areas prone to signal loss; avoid signal loss by adjusting equipment parameters; set up the local field ADS-B terminal.

(7) Upgrade ADS-B display software to enrich and improve various information in displays; obtain the required information by cable or from other control units; add the departure program and glide path analog signal to the image.

(8) Through video conference, telephone, intercom and other means airport personnel information exchange is strengthened; add a 360degree camera and connect the video data to the remote tower as an emergency backup.

(9) Increase the information communication with the staff of the remote tower, and understand the surface situation and clearance environment in real time; improve the clarity of the mosaic image, and calibrate the accuracy of the transmission image.

(10) Through video conference, telephone, intercom and other means airport personnel information exchange is strengthened and timely understand the weather situation; add a sensor backup device or add an automatic station to the manual observation field.

(11) Properly match the on-duty force, strictly control the duty time of the controller, and manage the fatigue of the controller; continue to increase the number of control personnel.

(12) After power failure, the remote tower shall immediately take command; improve personnel emergency level, improve the efficiency of emergency repair.

(13) Arrange shifts properly to ensure the energy of on-duty personnel; the on-duty personnel shall strengthen the supervision of the on-duty personnel of the other tower through the video conference system.

4. Conclusion

In this paper, the basic frame of remote tower is established, with an assessment about its reliability on safe operation through the safety risk management for the new type of technology, remote control tower operation. As a result, we list its potential hazards in operation, determine whether the risk is acceptable and the risk level is classified by setting up the possibility/severity matrix. Based on the risk level of each hazard source, risk mitigation strategy is adopted respectively. In combination with the actual operation situation, effectively feasible measures are proposed. In short, it is a beneficial exploration and attempt for the practical operation of remote tower.

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