RADIO FREQUENCY IDENTIFICATION LOCATION & COMMUNICATIONBASED TRAIN CONTROL SYSTEM IN QINGHAI-TIBET RAILWAY OF CHINA

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Abstract : Considering the complex environment in Qinghai-Tibet, the traditional train track circuit control train system doesn't fit for this case. Therefore, a new kind technique of the train control system based on radio frequency identification's location and wireless communication system (RFL-CBTC) is introduced. In this paper, the whole system's primary structure, reliability and methods to improve safety are explained in detail.

Keyward: Qinghai-Tibet railway; Track circuit train control system(TCTC); Radio frequency identification location system(RFL); Communication based train control system(CBTC); Germu-Lasa railway

1 INTRODUCTION

The Qinghai-Tibet railway started to be constructed in 2001, which aims at accelerating the economic development of West China. About 84 percent of railway (965 km) lies in the altitude higher than 4 km. And 48 percent of railway, about 550 km, locates on frozen ground[1]. Qinghai-Tibet's complex environments include: low temperature, strong ultraviolet radiation, bad living condition, etc. Under such conditions, there are so many difficulties in designing, surveying, construction, logistics supply, operation control and management. At the same time, it raises problems on building roadbeds, tunnels, stations and so on. Most important, there is no electric power station along the railway so that we can't get enough power. If we choose the current track circuit control system, all the above disadvantages will affect the track circuit parameters, seriously leading to improper work status, and even endanger the safety of train. Therefore, a new kind of train location and data transfer system: radio frequency identification's location and wireless communication train control system should be adopted.

2 PRINCIPLE OF TCTC AND RFL-CBTC

2.1 TCTC

Track Circuit Train Control (TCTC)system transfers control information through railway track. Each track circuit is a close division with certain length. Sender and receiver are located in the start and end of the division. All these track circuits will be connected to the station' s control center to check whether the division is occupied or not. Parameter, track circuit resistance, is crucial because it will influence the value of current transferred to the control center. For instance, if the resistance' s value is small, signal in sender decrease much more. The current in receiver is too week to be transferred to control center. At the time, track circuit will not indicate the train' s position.

2.2 TCTC' S UNFITNESS FOR QINGHAI-TIBET RAILWAY

Firstly, track circuit' s parameters are so sensitive to the environment that it isn' t robust enough in Qinghai-Tibet. Also, land structure along the Qinghai-Tibet railway will affect track circuit parameters, especially the rail resistances. It is easy to produce salt rime in the surface of the rail in some part of the Qinghai-Tibet railway, which is built on the salina. These rime are good conductor and make the resistance decrease considerably. In the area of frozen ground, the resistance varies greatly from summer to winter, from day to night, so that the track circuit is not be stable for the safety of the train.

Secondly, thunders endanger the track circuit and signal equipments. The local thunder is rather special and it travels along the land. There are about 70 days with thunders in one year. It is a critical factor that needs to be considered.

Thirdly, there are few people living along the Qinghai-Tibet railway for the bad living condition. However, track circuits need a lot of people to maintain.

Fourthly, track circuits require a great deal of costly cables. It will cost about 50 to 60 percent of whole fund used for signal equipment.

Fifthly, the equipments of central system are put in the relay room of stations. The distance between two stations should be less than 20 km during electric hauling districts, or less than 30 km during gas combustion hauling districts. However, some districts in Qinghai-Tibet railway are 100 kilometers long, great exceeding the limit.

From the discussion above, we can safely draw the conclusion that we can' t choose the TCTC system in Qinghai-Tibet railway.

2.3 RFL-CBTC INTRODUCTION

2.3.1 RFL

The typical Radio frequency identification location system(RFL) is made up of RF-card, Read/Write device and management system etc. RF-card can read or write intelligently within encrypted communication[2]. Read/Write devices consist of wireless transceiver, antenna, controlling module and interface circuit and so on. There is no battery in RF-card because the power is provided by the radio frequency sent out by Read/Write device. The RF-card receives the radio frequency, rectify and charge capacitance up. The demodulator will demodulate the data from the radio frequency pulse, and then send the data to controlling logic circuit that executes storing, sending and other operations. EPROM of RF-card is used to store the ID of RF-card and other user's data. It can work at high frequency so as to be distinguished after a long distance.

RFL system can be divided into low frequency, intermediate frequency and high frequency according to their working frequency. The low frequency system refers to 100-500kHz and intermediate frequency system is about between 10-15 MHz. They are mainly used in short distance or low cost application. While the high frequency system works at 850-950MHz or 2.4-5 GHz. It is applied to the situation within long distance or high rate of reading/writing data. At present, high-speed (over 200 km) RFS systems working at high frequency are used in many fields, such as high way RFIDS in American.

The most important feature of RFL system is untouched distinguishing. Also it has other features such as less maintenance, low price and long life.

2.3.2 CBTC

CBTC is an advanced control system using wireless communication. With the great advantage attained from modern communication techniques, the wireless communication has been successfully applied into navigation and traffic fields etc. It's a flexible and safe new generation of train control system with strong functions and represents the trend of the future train control system. Now, there are some typical systems, such as ETCS in Europe, ATCS in North America, and so on. Generally, there are 5 parts in CBTC: MSC, BSC, BTS, MS and CL.

MCS: mobile switch center
BSC: base switch controller
BTS: base transfer station
MS: mobile station
CL: connection line

3 RFL-CBTC STRUCTURE AND RELIABILITY ANALYSIS

The RFL-CBTC system is ideal for improving the safety for following reasons: All the main devices and the RF-card are designed with hot backup; the wireless network could cover overlap districts to realize backup.

3.1 RFL SYSTEM IN GERMU-LASA

RFL consists of two main parts: RF-read/write device and RF-card (no power electric label). RF-read/write device is equipped on the train; the RF-card is embedded into the rail.

RFL works on the 3G frequencies. The read/write device moving speed is 200 km (the train limited-speed is 140 km/h in Qinghai-Tibet railway) compared to RF-card, and the distances between them is 1.2 m.

Two RF-read/write devices will be installed at bottom of the train. About 24000 RF-card will be placed on the train line from Germu to Lasa (1114 km). The interval of embedded RF-card is 100 m in the area between the stations. In the area at the station, the interval is 5 m

(Fig.1).

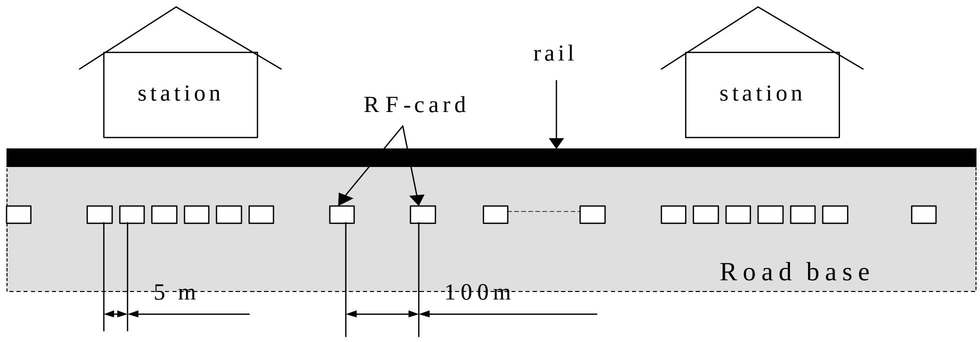

Fig.1 Interval

The distance is 30 cm from embedded RF-card to rail surface. The Fig.2 shows that.

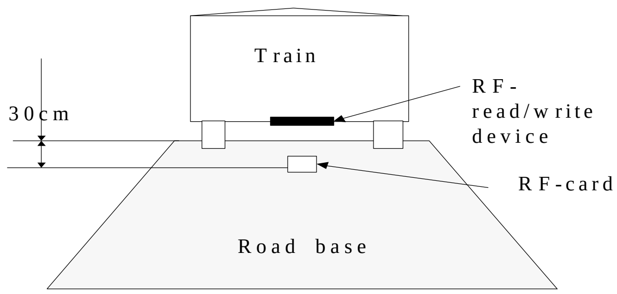

Fig. 2 Distance

The RF-card stores following data: card number, mileage, limited speed, railway status (up /down line, repairing etc).

3.2 CBTC SYSTEM IN GERMU-LASA

The system includes two sets of Remote Base Center(RBC) + MSC(one in the Germu, aother in Lasa, hot backup), 10 BSC in the middle stations, 50 BTS along the line, 50 MS (50 trains) moving on the rail (Fig.3). RBC1 and RBC2 backup each other. Circularity-line is used to connect the BCS and BTS. All BSC, BTS, MS are designed to have duplex backup. The structure is shown in Fig.3

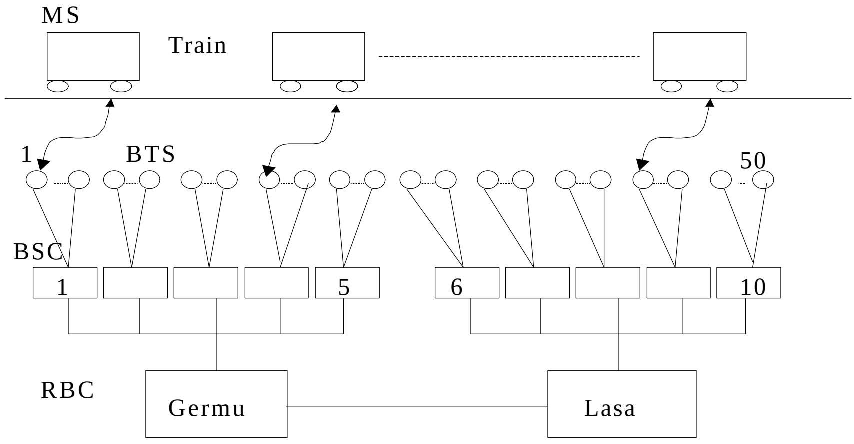

Fig.3 Structure

3.3 WORKING PROCEDURE

When train is running on the railway, the RF-read/write device will read the data from the RF-card. This information will immediately be displayed to the train driver and transferred to control center through the CBTC. Therefore, the train' s position is located. When the train runs between two RF-cards, the location could be calculate by formula:

Location= Mileage(data from just passing RF-card)+Speed*Time . (1)

The control center will monitor and control train' s running through the CBTC according to train' s location.

3.4 SYSTEM' S MAIN PART MARKOV MODEL AND RELIABILITY' S ANALYSIS

The system' s reliability means that it can accomplish normal functions under any conditions at time without being interrupted. The main reliability factor of repairable system is: Reliability(t) and Mean Time Between Failure (MTBF). In real applications, MTBF is the most important factor. The MTBF formula is[3]:

$$MTBF=\int_0^{\infty} R(t)\,dt = -Q_w(0)B^{-1}e_w = \sum_{i=0}^{k} t_i \quad (2)$$

t_0, t_1….., t_k is the result of equation: $(t_0\ t_1 \ldots\ldots t_k)B = -(Q_0\ (0)\ Q_1\ (0)\ \ldots\ldots Q_k)$. Q is normal state. e_w is an array which value is 1.

As to RFL-CBTC, a repairable system, which can be simplified into six serial different models. It is shown in Fig. 4.

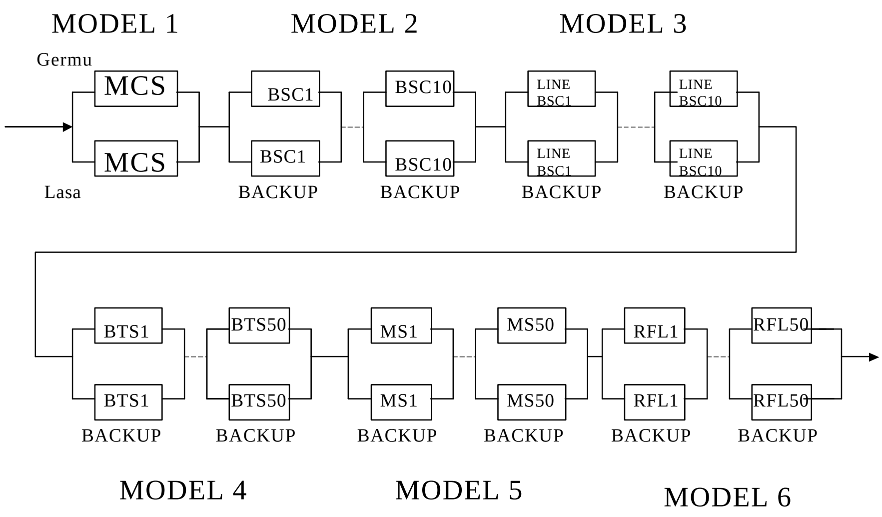

Fig. 4 Model

So this system state can be expressed as a continuing-time, and variance-state's Markov procedure. And Fig .5 shows system's reliable Markov model's transition procedure.

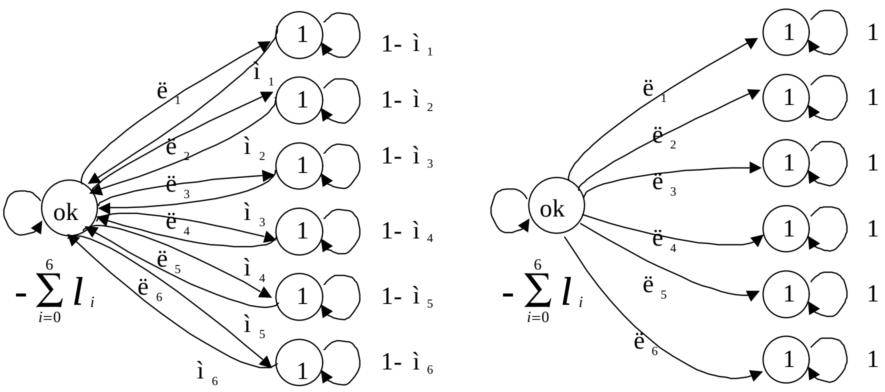

Fig. 5 Transition chart

According to the Fig. 5, the Markov transition matrix is

$$
A^{*} = \begin{vmatrix} -\sum_{i=0}^{6} l_i & {}_1 \cdots\cdots {}_6 \\ 0 \quad 0 & \ldots\ldots 0 \\ \vdots \quad \vdots & \vdots \\ 0 \quad 0 & \ldots\ldots 0 \end{vmatrix} \tag{3}
$$

So the repairable serial system's Markov reliability's equations is:

$$R(t) = Q_0(t) = e^{-(\sum_{i=0}^{6} l_i)t} \tag{4}$$

The serial MTBF equation is:

$$MTBF = \int_0^{\infty} R(t)\,dt = \frac{1}{\sum_{i=0}^{6} l_i} \tag{5}$$

The same hardware parallel system's MTBF equation is [4]:

$$MTBF = \frac{3l + m}{2l^2} \tag{6}$$

The parameters of hardware are listed in Table 1:

Table 1 Parameter

HARDWARE	MTBF(hour)		
MSC	100000	0.00001	4
BSC	200000	0.000005	4
CL	10000	0.0001	0.1
BTS	35000	0.0000286	0.5
MS	30000	0.0000333	0.25
RFL	10000	0.0001	0.2

With the equation (5), (6) and table 1, we can calculate the system model's MTBF and (Table 2) :

Table 2 Parameter

MODEL	TYPE	Method	MTBF(hour)	
MODEL 1	MSC	1P	$2*10^{10}$	$0.5*10^{-10}$
MODEL2	BSC	10S (1P)	$0.8*10^{10}$	$1.25*10^{-10}$
MODEL 3	CL	10S(1P)	$0.5*10^{6}$	$2*10^{-6}$
MODEL 4	BTS	50S(1P)	$6.1*10^{6}$	$0.164*10^{-6}$
MODEL 5	MS	50S(1P)	$2.255*10^{6}$	$0.44*10^{-6}$
MODEL 6	RFL	50S(1P)	$0.2*10^{6}$	$5*10^{-6}$

* P = parallel S = serial

According to the Table 2 and equation (5), the system's MTBF = $0.13*10^{6}$

Since the standard of the train's main control system's MTBF is no less than 10000h in China, this new system satisfies the requirement very well.

4 CONCLUSIONS

It is obviously that this new technique of the train control system based on radio frequency identification's location and wireless communication can provide better stableness, safety, and accuracy than TCTC in Qinghai-Tibet railway. Also, it's easy maintainability and high automation level will make the whole system more reliable. From the detail discussion above, we can affirm that this system (RFL-CBTC) should be adopted. The RFL-CBTC system would have bright future in modern train control system.

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