Information Model Construction and State Analysis Strategy for Vital Signs of Power Network Inspector

Yining Gang\textsuperscript{1,a}, Wei Li, Yongbin Zhao, Chengming Jin, Jun Liu\textsuperscript{2,b}, Junkai Zhang, Yuedong Hao\textsuperscript{3,c}\textsuperscript{*}

\textsuperscript{1}State Grid Corporation of China, Liaoning Electric Power Supply CO., LTD, Shenyang 110004, China
\textsuperscript{2}State Grid Corporation of China, Liaoning Electric Power Supply CO., LTD, Shenyang 110004, China
\textsuperscript{3}State Grid Corporation of China, NARI Group Corporation Information, Technology and Communication Company, Nanjing 211000, China
\textsuperscript{a}yininggang@gmail.com \textsuperscript{b}weili@gmail.com \textsuperscript{c}*yuedonghao@gmail.com

Abstract—Based on the requirement for protecting life safety of electric workers, the vital signs information model which consists of real time vital signs model, fatigue degree evaluation model and vital signs trends model is designed and implemented. The model is based on data collected, including basic attributes, heart rate, body temperature, blood pressure and Work scenarios. Besides, the most suitable vital signs historical data for each power maintenance personnel is calculated by the national standard and personal historical data. The model not only enhances the supervisory means of the guardians, but also greatly improves the production efficiency of the inspectors on the electric power field.

1. INTRODUCTION
At present, the environment of power network \textsuperscript{[1-2]} is harsh, and there is lots of equipment, which has complex operation. But the inspectors operate and maintain the equipment only by their experiment and the manual. They can’t timely observe the dangerous situation, which would results in accidents. Therefore, it is necessary to build the information model construction and state analysis strategy for vital signs of power network inspector based on big data technology. The model not only enhances the supervisory means of the guardians, but also greatly improves the production efficiency of the inspectors on the electric power field.

In past decades, researchers have proposed some approaches to meet the needs: A research proposed by Fernández-López H \textsuperscript{3} introduces HM4All, a remote vital signs monitoring system, and presents a prototype system being deployed in a hospital internment floor. Its architecture, original network topology, software applications and wireless sensors are described. Similarly, M Corporation \textsuperscript{4} proposed a method pertains to devices and methods for increasing the ease of data gathering and efficiency of information flow in a clinical setting. The devices of the present invention comprise medical examination tables, dental examination chairs and vital signs monitors, all of which further comprise integrated hardware and software that allow these devices to effectively collect and communicate data in a manner that allows for greater ease of use of these devices and subsequent increased efficiency in the clinical space on the part of the clinician. The medical examination tables and dental examination chairs of the present invention preferably include at least one load sensor for
measuring a subject’s weight when the subject is seated thereon. The methods of the present invention are directed at using the aforementioned devices to increase ease of data collection and efficiency of care delivery within a space in which the devices are used. JJ Perez [5] presents a wireless systematic architecture, a hardware and software platform based on low-power integrated circuits, on-chip signal processing components and communications. The structure of such architecture consists of lightweight miniature nodes placed strategically on patients to allow non-invasive, continuous and ambulatory health monitoring and inexpensive, to provide medical readings on local devices and clinical records applications on web browsers and mobile devices. The main goal of this project is the development of an autonomous wireless monitoring system for vital signs with battery-powered nodes and medical sensors. It acquires, stores and transmits signals to determine the states of oxygenation, heart and respiratory rates, and temperature in real time to a central monitoring station that integrates a touchscreen graphical interface and mini-OLED displays. This work provides self-monitored environments minimizing the requirements for primary needs, early medical attention, optimizing premature diagnosis and comfort of patients, through a set of algorithms that contribute to the performance of the nodes generating significant benefits on human lifetime through early disease detection. In addition, other researchers [6-12] have also done a lot of research in this area, and they made a very remarkable and effective contribution which is meaningful for the present research.

In this paper, information model construction and state analysis strategy for vital signs of power network inspector is proposed. We will discuss the vital signs of personnel in Sect. 2. The information model of vital signs is described in Sect. 3. Section 4 describes the simulations and experiments, followed by the concluding remarks.

2. VITAL SIGNS OF PERSONNEL

In order to build information model of vital signs of power network inspector, vital signs of personnel which consists of 5 parts is proposed as the following figure.

![Vital signs of personnel](image)

2.1 Basic attributes

Power Network Inspectors have the following basic attributes, including height, weight, sex and age. Among them, the age attribute is generally 5 years as a cycle.

2.2 Heart rate

Heart rate refers to the number of heart beats per minute in a quiet state. Individual differences may occur due to age, sex or other physiological factors. Generally, the younger you are, the faster your heart rate is, and the faster your heart rate is in women than in men of the same age. These are all normal physiological phenomena. In quiet state, the normal heart rate of adults is 60-100 beats per minute, and the ideal heart rate is 55-70 beats per minute. Heart rate changes are closely related to heart
disease. If the heart rate is more than 160 beats per minute, or less than 40 beats per minute, mostly in patients with heart disease, should be examined in detail as early as possible in order to treat the cause.

There are two main types of heart rate sensing: one is the measurement of light reflection, the other is the measurement of potential. The biggest problem of the potential technology is that it can’t read the data actively. It needs the operator to measure it consciously, so that it can’t realize remote monitoring. The photoelectric measurement can be operated by one hand. It can read the data actively and read the data remotely. It is more suitable for the service of the large data. The light reflection technology is greatly influenced by the environment, and even different colors of skin will affect the signal link. Therefore, the light reflection technology needs to do a lot of processing in the back-end circuit. Because of the field operation in the field of electric power production, the large amplitude of the personnel movement will inevitably affect the position of the intelligent hand ring, thus it will affect the accuracy of the light reflection technology, so the potential technology is more suitable for the field application of the electric power production operation.

2.3 Body temperature
The body temperature of the healthy person is relatively constant. Traditionally, the normal body temperature is considered to be 37 degrees Celsius, but it is influenced by factors such as location, time, season and individual differences. For example: the body temperature is higher in the afternoon than in the morning; after meals, labor or vigorous exercise, the body temperature can also be slightly increased; sudden entry into high temperature environment or emotional excitement and other factors can also make the body temperature slightly rise. Generally, the body temperature of young people is higher than that old people because of their high metabolic rate.

Thermometers can be used to test the temperature of power network inspector.

2.4 Blood pressure
Blood pressure (BP) refers to the lateral pressure of blood acting on the wall of blood vessels per unit area when it flows in blood vessels. It is the power to promote blood flow in blood vessels. Blood pressure is usually referred to as arterial blood pressure.

The blood pressure range of the health person in quiet state is stable. The systolic blood pressure is 90-139 mmHg, the diastolic blood pressure is 60-89 mmHg, and the pulse pressure is 30-40 mmHg.

Hypertension refers to systolic blood pressure more than 140 mmHg or diastolic blood pressure more than 90 mmHg without antihypertensive drugs. Hypotension is defined as blood pressure less than 90/60mmHg.

There are two main ways of blood pressure sensing technology: one is the use of pressure sensors measurement, the other is the use of optical measurement. Products using pressure sensors, such as BP pro smart Bracelet developed in Singapore, have been certified by FDA. But the price is expensive, so pressure sensor measurement technology is not considered. The use of optical measurement in Israel Corp has a successful case, and the gap between the domestic technical level and the international level is gradually narrowing. The principle of optical measurement technology is based on the assumption that the blood is an ideal fluid, so the stability of the light source, the difference of individual (the degree of weight and the distribution of blood vessel), and the advanced character of signal processing technology will all affect the accuracy and stability of the blood pressure measurement. In the future, the main direction of the optical measurement technology to improve the stability and accuracy of the blood pressure measurement is based on the rational selection of hardware, the clinical trial of large samples, and the optimization of the algorithm.

2.5 Work scenarios
The information model of the physical sign state can be set up according to the following 6 kinds of substation inspection work environment. According to the natural environment, it can be divided into indoor GIS and outdoor. According to the type of inspection and the workload, it can be divided into comprehensive inspection, routine inspection and special inspection.
3. INFORMATION MODEL OF VITAL SIGNS

Research on information model and analysis technology of vital signs based on physiological sensors. In the work scene of the substation inspection, the information of the real-time collection of the inspectors’ heart rate, body temperature, blood pressure and the quality of patrol work is set up to establish the information model, so as to realize the comprehensive analysis about the inspectors’ real-time vital signs, degree of fatigue and the change trend of the physical signs.

The vital signs information model consists of real time vital signs model, fatigue degree evaluation model and vital signs trends model.

3.1 Real time vital signs sub model

The real time vital signs model is to calculate the most suitable threshold range of target personnel based on the national standard and personal historical data.

Set $R_0(\text{max})$ and $R_0(\text{min})$ is the national standard threshold range of the index including heart rate, body temperature and blood pressure, etc. And $R_{ij}(\text{max})$ and $R_{ij}(\text{min})$ is the index threshold range at $i$-th day and $j$-th hour of the target personnel. The $m$, $n$, $\alpha$ and $\beta$ can be set by users, and $\beta=1-\alpha$, so the suitable threshold range $[R(\text{max}), R(\text{min})]$ can be calculated in the following two equations.

$$R(\text{max}) = \alpha R_0(\text{max}) + \frac{\beta \sum_{i=1}^{m} \sum_{j=1}^{n} R_{ij}(\text{max})}{m(2n+1)}$$

$$R(\text{min}) = \alpha R_0(\text{min}) + \frac{\beta \sum_{i=1}^{m} \sum_{j=1}^{n} R_{ij}(\text{min})}{m(2n+1)}$$

When the index is at a specific value, the corresponding coping styles can be expressed by equation 3. In case 1, it means the index is in reasonable limits. In case 2, the index are not normal, and they need early warning. In case 3, there’s something wrong with the index, and it needs alarm. In case 1, the index are very dangerous and need to be dispatched in time.

$$R \in \begin{cases} [p-r_q, p+r_q] & \text{(Case 1)} \\ \left[R(\text{min}), p-r_q\right) \cup (p+r_q, R(\text{max})] & \text{(Case 2)} \\ \left[p-r_q, R(\text{min})\right) \cup (R(\text{max}), p+r_q] & \text{(Case 3)} \\ \text{other (Case 4)} \\ \end{cases}$$

Figure 2. The vital signs information model
In the above equation, \( r_1 \) and \( r_2 \) is set by the users, and \( r_1 < 1, r_2 > 1 \). Besides, the \( p \) and \( q \) can be calculated as the following 2 equations.

\[
p = \frac{R(\text{max}) + R(\text{min})}{2} \quad (4)
\]

\[
q = \frac{R(\text{max}) - R(\text{min})}{2} \quad (5)
\]

### 3.2 Fatigue Degree Evaluation Model

Fatigue is classified into mild, moderate and severe fatigue. Mild fatigue is restored after a short rest, which is a normal phenomenon; moderate fatigue has the feeling of fatigue, leg pain, palpitations; severe fatigue in addition to fatigue, leg pain, palpitations, but also headache, chest pain, nausea and even vomiting, and these signs last a long time.

Generally we use the basal heart rate, exercise heart rate and recovery heart rate to assess fatigue.

The basal heart rate is the heart rate resting in the morning after waking up. In general, the basal heart rate remains relatively stable. If the basal heart rate increases more than 8-10 times per minute after a night's recovery after a large amount of exercise training, fatigue can be considered to have not recovered. If the basal heart rate continues to be high for several consecutive days, it indicates excessive exercise. In this situation, the person needs to adjust the amount of exercise, and pay attention to rest.

The exercise heart rate is characterized by rapid change, rapid rise and fall with the increase or decrease of exercise intensity. In order to accurately assess exercise heart rate in timely, person needs to wear a heart rate band. The results showed that with the improvement of training level, the heart rate gradually decreased when the body completed the same load of exercise.

The speed of recovery heart rate after exercise also is used as an indicator of fatigue. If the heart rate does not return to near quiet level within 3-5 minutes after exercise, it indicates that the person is in the state of fatigue.

### 3.3 Vital signs trends model

The vital signs trends model is based on the real time vital signs model. When the index is close to the threshold and is in a rapidly changing state, it is necessary to conduct early warning.

According to the quantitative evaluation of the working status of the site operators and in combination with the information of the field personnel's physical signs, it is possible to confirm the extent of the personnel in the scope of the physical condition, to ensure the accuracy and reliability of the operation. If the result exceeds the range, then the guardianship need to warn the site operators and stop the operator work, ensure production safety.

### 4. Simulations and Experiments

The proposed model has been verified. With the advancement of the project, a provincial company was randomly selected from each branch as a pilot unit, and is shown in the following table:

| Divisions      | Pilot provincial companies |
|----------------|-----------------------------|
| North china grid | Beijing                     |
| East china grid  | Jiangsu                     |
To ensure the effectiveness and the accuracy of the proposed vital signs information model, an information system based is constructed to test its feasibility, and the verified result is shown in table 2:

Table II. The Validity of the Model

| Units                  | Alarm accuracy rate | Advance alarm time |
|------------------------|---------------------|--------------------|
| North china grid       | 93.7% (+12.2%)      | 2min39sec          |
| East china grid        | 97.4% (+8.2%)       | 2min35sec          |
| Central china grid     | 94.1% (+17.7%)      | 2min38sec          |
| Northeast china grid   | 93.1% (+11.9%)      | 2min40sec          |
| Northwest china grid   | 91.5% (+15.2%)      | 2min38sec          |
| Southwest china grid   | 90.5% (+19.6%)      | 2min36sec          |
| **Total**              | **93.3% (+13.2%)**  | **2min38sec**      |

Above all, the verified model shown: With the pilot application of related systems, the alarm accuracy rate form 80.1% upgrade to 93.3, and the average advance alarm time is 2 minutes and 38 seconds which is very meaningful.

5. CONCLUSIONS
By collecting the environment data including the information of human vital signs, warning, and working quality, it is integrated to analyze environmental factors and operators’ data (real time vital signs, fatigue tension and signs change trends), and form positive feedback with work quality data, so that we can establish large data information model of personnel safety in the electric power production environment.

ACKNOWLEDGMENT
This work was financially supported by the Research Project of Intelligent Wearable Work Support and Safety Monitoring Technology for Electric Power Production (Project No. SGLNXT00DKJS1700166 ). The authors wish to thank all the reviewers for their comments and suggestions, and appreciate previous researchers whose work helps us greatly. The authors are very grateful to members of state grid corporation of China for their proofreading of this paper and many useful suggestions on improvements.
REFERENCES
[1] Hao Y J, Sun J L, Liu G F. Design of the high-voltage power network remote monitor and control system[J]. International Electronic Elements, 2008.
[2] Qiang S, Zhao B, Liu W, et al. An Overview of Research on Smart DC Distribution Power Network[J]. Proceedings of the Csee, 2013, 33(25):9-19.
[3] Fernández-López H, Afonso J A, Correia J H, et al. HM4All: A vital signs monitoring system based in spatially distributed ZigBee networks[C]// Pervasive Computing Technologies for Healthcare. IEEE, 2010:1-4.
[4] Corporation M. Vital signs monitor for controlling power-adjustable examination table[J]. 2014.
[5] Perez J J, Saldarriaga A J, Bustamante J. A wireless body sensor network platform to measure vital signs in clinical monitoring[J]. 2013:1-6.
[6] Gao T, Greenspan D, Welsh M, et al. Vital Signs Monitoring and Patient Tracking Over a Wireless Network[C]// International Conference of the Engineering in Medicine & Biology Society. Conf Proc IEEE Eng Med Biol Soc, 2005:102.
[7] Gao T, Hauenstein L K, Alm A, et al. Vital signs monitoring and patient tracking over a wireless network[J]. Johns Hopkins Apl Technical Digest, 2005, 27(1):66-73.
[8] Shi H, Wang W, Xie F. Intelligence Monitoring System Based on Vital Signs of Driver[J]. Journal of Chongqing Institute of Technology, 2009.
[9] Leite C R, Sizilio G R, Neto A D, et al. A fuzzy model for processing and monitoring vital signs in ICU patients[J]. BioMedical Engineering OnLine, 10(1)(2011-08-03), 2011, 10(1):68-68.
[10] Adibuzzaman M, Love R, Love R. A personalized model for monitoring vital signs using camera of the smart phone[C]// ACM Symposium on Applied Computing. ACM, 2014:444-449.
[11] Adibuzzaman M, Love R, Love R. A personalized model for monitoring vital signs using camera of the smart phone[C]// ACM Symposium on Applied Computing. ACM, 2014:444-449.
[12] Almeida V, Nabney I T. Detecting dynamical changes in vital signs using switching Kalman filter[C]// Engineering in Medicine and Biology Society. IEEE, 2017:2223-2226.