Life Assessment of Thermally Upgraded Kraft Paper in Mineral Oil by Accelerated Aging Test

Katsunori MIYAGI

1 Introduction

A guideline for the design, application and operation of transformers using high-temperature insulating materials has recently been established as an IEC standard for achieving a low-carbon, environmentally-friendly society. Japan AE Power Systems has been examining heat deterioration characteristics within oil of thermally upgraded kraft paper (TUK) (Tomoegawa Paper Co., Ltd., nitrogen content: 2.2%), a type of heat-resistant insulating paper[1]. TUK is made of a chemically-treated cellulose-based material. The results of the study of TUK life assessment are summarized below.

2 Life estimation

2.1 Method of estimating life

The life of insulating paper used for transformer windings is generally considered to end when the average degree of polymerization (DP) of the cellulose in the paper falls to 450. The Arrehenius model is used for predicting life by an accelerated aging test. Using the percentage of retention, 45%, of the DP of insulating paper as the criterion for life assessment, a life prediction chart was created by an Arrehenius plot of the heating time and heating temperature to find when the criterion is reached. Note, however, that the data obtained at each heating temperature was subjected to a linear approximation depending on the test conditions (heating time and heating temperature) to estimate the lifetime at retained DP of 45%.

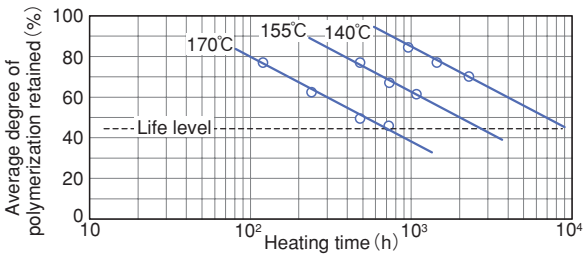
2.2 Results of life prediction

Data on TUK[1] and that on general kraft paper[2] were used for life assessment. Fig. 1 and 2 illustrate the change with time of retained DP of the two types of paper, respectively. The lifetime (at retained DP of 45%) was estimated by linear approximation.

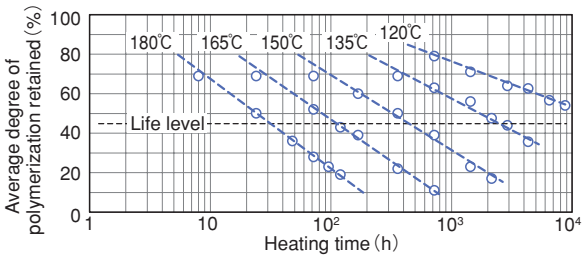
Fig. 3 illustrates the results of the Arrehenius plot conducted based on the relation between lifetime and heating temperature obtained by this method. The horizontal axis represents both temperature t (˚C) and 1/T (= t + 273). The chart indicates that TUK can be used continuously at approximately 109˚C to ensure the life of 30 years, whereas general kraft paper must be used at 98˚C.

3 Conclusion

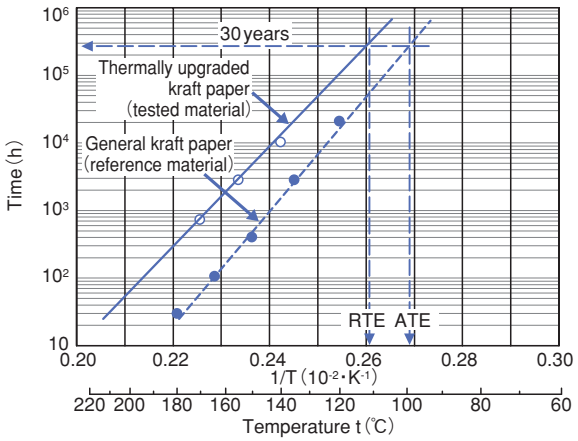
Life assessment recommended by the Electric Technology Research Association in Japan was conducted based on the data obtained by the accelerated aging test of TUK in mineral oil. The obtained results indicate that the heat performance of TUK is higher than that of general kraft paper by approximately 10˚C, assuming continuous rated operation for 30 years.



[Fig. 1] Change with time of thermally upgraded kraft paper



[Fig. 2] Change with time of general kraft paper



[Fig. 3] Life assessment by Arrehenius plotting (based on retained DP of 45%)

Reference

[1] N. Yamagata et al., "Diagnosis of Thermal Degradation for Thermally Upgraded Paper in Mineral Oil," CMD 2008, pp. 1000-1004 (2008)

[2] Sakai et al., "Thermal Degradation Characteristics of Insulating Paper for Transformers," Abstracts of the 21st Insulating Oil Committee Workshop of the Japan Petroleum Institute, pp. 50-53 (2001)

Research study report

Technology to Increase the Operating Speed of Spring-operated Mechanisms for Circuit Breakers

Kenichi OKUBO

1 Introduction

To drive gas circuit breakers (GCB) of 204kV or higher, operating mechanisms using high-pressure air or hydraulic pressure have been used. However, spring-operated mechanisms, which are easy to maintain, are now increasingly being used. In Japan, GCBs of 3-cycle interrupting time is applied for 168kV or and 2-cycle interrupting time for 204kV. Therefore speed of the operating mechanism must be increased to use it for GCB of 204kV or higher.

2 Problems in increasing the speed

Fig. 1 illustrates the structure of a spring-operated mechanism. The tripping control mechanism related to the tripping operation consists of a solenoid and three levers.

Fig. 2 illustrates the time division from the moment of giving a tripping command to the opening of the GCB. Period *t1* is from the moment of a tripping command to the breaking of engagement between the tripping trigger and the intermediate lever, *t2* is the duration until the interrupting spring is actuated, and *t3* is the period up to the opening of the GCB. With a 3-cycle GCB, the ratio *t1:t2:t3* is 0.6:0.15:0.25, assuming that the opening time is 1. It is therefore essential to decrease *t1*, the operating time of the solenoid, to increase the operating speed of the GCB.

3 Details of study on increasing the speed

Fig. 3 illustrates the structure of a solenoid. To increase the speed of the solenoid, the following parameters were examined.

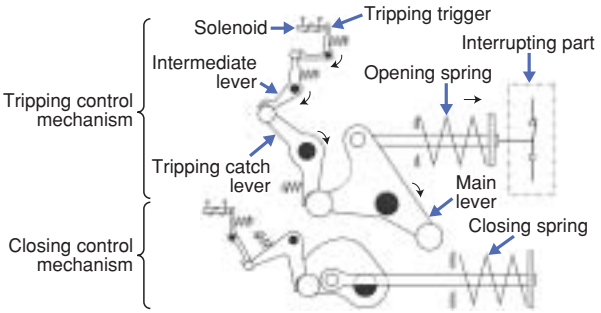
(A) Core material: Silicon steel, which is hardly affected by eddy currents and allows magnetic flux to pass through easily, is used to ensure high-speed response.

(B) Coil turns: By using a roller bearing for the sliding part of the tripping mechanism, thus reducing the load on the solenoid, coil turns can be decreased to reduce the startup time of coil current.

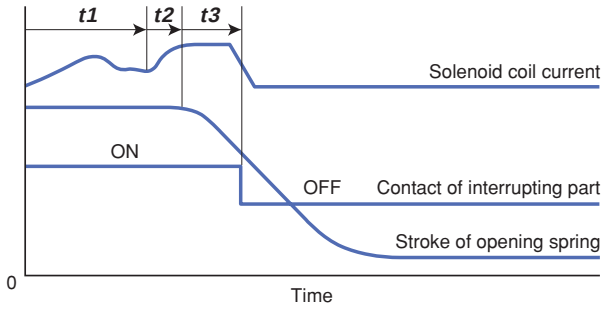
(C) Plunger stroke: Governor gain of the tripping coil is increased to minimize the stroke.

(D) Core shape: Reduced coil capacity in (B) decreases the core height and magnetic path length.

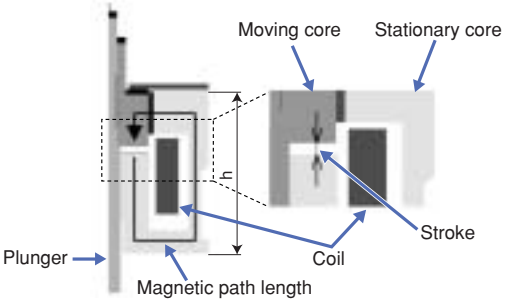
The coupled analysis of plunger operation and moving magnetic field conducted on the above parameters confirmed that *t1* could be shortened by 65%. It was also confirmed that of all the items studied, reducing the stroke was most effective for reducing *t1*. In addition, *t2* and *t3* were shortened by reducing the weight of parts and improving mechanisms, and as a result a spring-operated driving mechanism that satisfies 2-cycle interrupting specifications was developed.



[Fig. 1] Structure of spring-operated mechanism



[Fig. 2] Definition of time division



[Fig. 3] Structure of solenoid

Reference

H. Hashimoto et al., "Speed-up Technology for Ultra-high-voltage Large-capacity GCB," Collection of papers for the national convention of the Institute of Electrical Engineers of Japan, No. 6-223, pp. 376-377

Study of Surface Conditions of Cu-Cr Electrode for Vacuum Interrupters

Hiromasa SATO Yoshihiko MATSUI Yasushi NODA

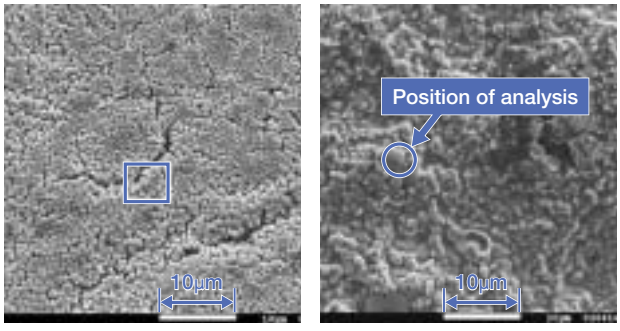
1 Introduction

Gas circuit breakers (GCB), which use SF_6 gas as an arc-quenching medium, have been used mainly as high-voltage power circuit breakers. In line with the increasing attention on techniques to reduce environmental load in recent years, efforts are being made to achieve vacuum circuit breakers (VCB) of higher voltage and larger capacity using a vacuum as an arc-quenching medium to reduce the amount of SF_6 gas, which has high global warming potential. To assess the effect of the magnitude of interrupting current on the surface state of electrodes, the surface conditions of the copper-chromium (Cu-Cr) electrode materials used for high-voltage VCB were examined.

2 Analytical survey

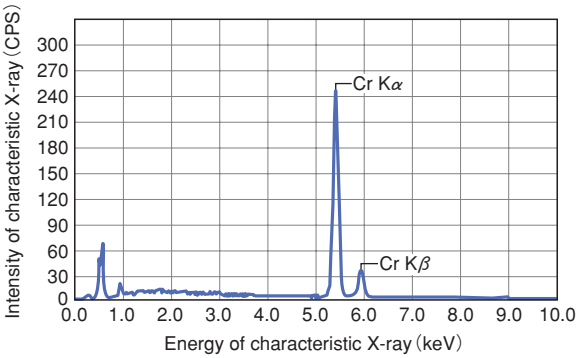
It is known that the surface conditions of Cu-Cr electrodes after an interrupting test vary depending on the polarity, namely the melting on the anode side is severe. Arc observation also indicates that in some cases, the anode melts more severely in a region where the interrupting current is large. After an interrupting test, an anode melted layer was examined using a scanning electron microscope and energy dispersive X-ray spectrometer. A current of 5kA was selected for mild melting of the anode, and 20kA to 40kA for severe melting.

The surface of the anode after the interruption of a 5kA current as shown in Fig. 1(a) reveals a fine particulate state of 1 μm or smaller. Meanwhile, on the surface examined after the interruption of 40kA as shown in Fig. 1(b), scattered particles of various sizes were found, with the largest being approximately 5 μm. Component analysis showed that the particles were Cr (Fig. 2).



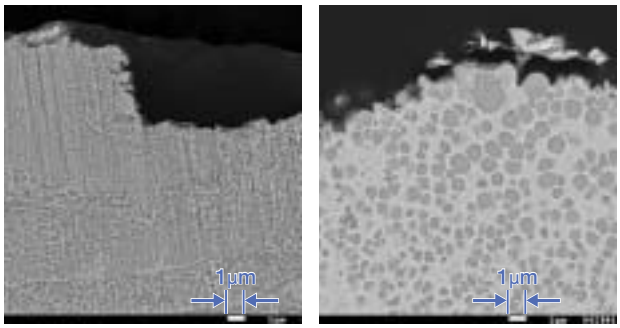
(a) After the interruption of 5kA (b) After the interruption of 40kA

[Fig. 1] Surface of anode after current interruption



[Fig. 2] Component analysis of large particles (Fig. 1 (b))

Fig. 3 shows the cross-sectional area of the melted layer examined. Fig. 3(a) shows the cross-sectional area of the melted layer after the interruption of 5kA. The Cr particles within Cu were fine and uniform. With the interrupting current of 20kA, larger Cr particles were found to be scattered similar to the surface. The difference in the conditions of the melted layer by current value is due to the difference in cooling rate due to different melting depths.



(a) After the interruption of 5kA (b) After the interruption of 20kA

[Fig. 3] Cross-sectional area of the melted layer after the current interruption

3 Conclusion

The conditions of the melted layer varied between the current region where the effect on the anode was small and the region where the effect was large. In the latter, larger Cr particles were found to be scattered within Cu. We will improve the performance of VI by clarifying the relation between the surface conditions and current interrupting performance.

TOPICS

1 Degradation Diagnosis of Large-capacity Transformers

High accuracy is required in diagnosing the degradation of aging power transmission and distribution equipment. To present optimum maintenance and replacement plans for aging transformers to our users, Japan AE Power Systems has been developing high-accuracy degradation and residual life diagnostic methods. In collaboration with Electric Power Development Co., Ltd., we examined the degree of degradation of various materials, including the degree of polymerization of insulating paper, taking the opportunity of replacing the approximately 40-year-old 265MVA transformer. The results matched the residual life estimated in advance. We will continue to gather data to improve the accuracy of our degradation diagnostic technology.

Hoisting the winding of an aged transformer

2 Lightning Arresters

Japan AE Power Systems has a wide range of lightning arresters conforming to major international standards including IEEE, IEC and JEC. We have many voltage classes, including 22kV to 1,100kV for tank-type lightning arresters used for gas insulated switchgear (GIS), 3.3kV to 550kV for the porcelain bushing type used for gas circuit breakers and 66kV to 300kV for polymer insulator type lightning arresters. A high withstand voltage zinc-oxide element having a voltage per unit thickness twice as high as that of the conventional model is used for tank type arresters to reduce the size of the product. We have a good selection and supply record of delivering lightning arresters, including those for DC power transmission lines, AC/DC converters, generator protection, and railway feeders. We can also provide lightning arresters and absorbers for special applications.

Tank type lightning arrester for 550kV GIS

266kV polymer insulator type lightning arrester

3 New Production Line of Environment-friendly VCB

The Numazu Works of Japan AE Power Systems set up a new production line for environment-friendly vacuum circuit breakers (VCB) using dry air instead of the conventional SF_6 gas. To build this new, more efficient production line, we thoroughly analyzed the problems of the existing lines, changed the line shape to minimize its length, introduced exclusive assembly facilities, enhanced the testing facilities, and then created three more such lines. This investment in facilities has increased the maximum production capacity of the environment-friendly VCB to 480 units/year. The product is starting to be delivered to environment-conscious countries including the U.S. and Australia, as well as the domestic market.

Environment-friendly VCB production line

4 Medium-size Transformers for the Ministry of Electricity in Iraq

Japan AE Power Systems has delivered more than one hundred sets of 25MVA- to 90MVA-class 132kV transformers for power transmission to the Ministry of Electricity in Iraq through Meidensha Corporation* since 2004 to supply power to the areas of the country that are being rebuilt. Due to the difficulty of sending our instructors for field assembly, we trained engineers of the Ministry of Electricity at the factories on how to maintain quality after field assembly. We will continue playing an important role in the reconstruction of Iraq together with Meidensha Corporation.

132kV mobile substation

* Japan AE Power Systems supplied products to Meidensha Corporation.

5 AE Green Factory: Minimizing the Environmental Load

Japan AE Power Systems makes utmost effort to improve its business processes by creating an appropriate company-wide organization, and aims to turn the company into the “AE Green Factory” with the minimum environmental load. We have set numerical five-year reduction targets for energy consumption, CO_2 emissions, and the quantities of waste and toxic chemical substances. Our activities include examining energy consumption as a contractor designated by the revised Energy Saving Act* in cooperation with experienced external company, in order to rationalize consumption by reducing the operating loss of their combustion-type steam boilers.

Checking the combustion status of the boiler

* Revised Energy Saving Act :
“Act on Temporary Measures for Promotion of Rational Uses of Energy and Recycled Resources in Business Activities” enforced in April 2010

6 24kV Cubicle-Type Gas Insulated Switchgear for Singapore

Japan AE Power System started delivering 24kV cubicle-type gas insulated switchgear (C-GIS) conforming to the new IEC standard in 2005. This C-GIS is a competitive product achieved by sharing and simplifying parts. We have been successively supplying the product to Singapore, with approximately 6,500 sets sold (including scheduled ones). Furthermore, a number of environment-friendly 24kV dry air-insulated C-GISs, which we started to supply in 2010, are used as major equipment for power distribution facilities in Singapore.

24kV dry air-insulated C-GIS

7 362kV Gas Circuit Breaker for the U.S. Market

HVB AE Power Systems, an affiliated company of the Japan AE Power System group in the U.S., is providing 72.5kV to 800kV gas insulated circuit breakers (GCB) to power utilities all over the U.S. In particular, over one hundred 362kV GCBs were delivered in 2010 because of their high performance and reliability. We are currently delivering both conventional pneumatically-operated and hydraulically-operated models at the request of our users, but aim to accelerate the transfer to the hydraulically-operated GCB which offers improved performance and economic efficiency, thus expanding the use of 362V GCB in the U.S. market.

362kV dead tank type gas circuit breaker

8 Leading Supplier in Bahrain

The Kingdom of Bahrain is an island nation located in the Arabian Bay, and is about the size of Singapore Island. Japan AE Power Systems has been delivering various substation equipment such as gas-insulated switchgear and transformers to many of its 220kV and 66kV substations, which are the main power network systems of the nation, since the 1980s. We have being supplying a number of our products for power infrastructure and industry, including those for the aluminum smelting and steel industries, which are the major industries of the nation and on a par with petroleum refining, and for urban development by private developers and industrial complex development. Thus, we cover the entire power distribution field and are a key supplier with a strong presence.

Urban development in Manama, the capital of Bahrain

9 Secondary Use of Palm Fatty Acid Ester Insulating Oil

Japan AE Power Systems has developed palm fatty acid ester (PFAE) insulating oil as an alternative insulating medium for transformers instead of mineral oil, and is currently studying how to use waste PFAE oil effectively in cooperation with the Kanazawa Institute of Technology. Waste mineral oil is generally treated by combustion at present, but since PFAE oil is low-viscosity plant-based oil, secondary use as diesel fuel might be possible, and so we are currently investigating the feasibility of this approach. If PFAE could be used as a fuel for diesel engines in various fields, CO_2 emissions would be reduced significantly, thus helping to create a recycling-based society.

Transformer using PFAE oil

Affiliated company in China

New plant inaugurated in August 2010

Shanghai AE Power Changcheng Switchgear Corporation

Shanghai AE Power Changcheng Switchgear Corporation is a Japan-China joint venture established in 2004 with Tianshui Changcheng Switchgear Factory, our Chinese partner, as a production center for medium-voltage switchgear in China. We mainly manufacture 40.5kV cubicle-type gas insulated switchgear (C-GIS) and 55kV vacuum circuit breakers (VCB) in this new plant constructed in the North Jiading Industrial District located 40km northwest of Shanghai, and sell them in the Chinese market. Our landmark first delivery, a 45.5kV C-GIS, is currently being used as substation equipment for the Qinghai line, a highland railway connecting Lhasa in the Tibetan Autonomous Region to Xining in Qinhai Province at an altitude as high as 3,000m. We have already provided a number of products in the six years since establishment and the joint venture is growing steadily.

The Jiading District where our company is located is a satellite city of Shanghai, which is growing at an astonishing pace. The Shanghai International Circuit is nearby, where the Chinese F1 Grand Prix is held every year. We started operation in 2004, but in 2006, we were suddenly ordered by the government of Shanghai to evacuate to make way for an urban development plan. Along with many neighboring foreign firms that had set up there at around the same time, we were required to move and started operation in the new plant in August 2010. After this unexpected move, we increased the production capacity of our C-GIS and VCB by 20%, and created a new production line for the 72kV environment-friendly VCB. Approximately 50 local employees are currently manufacturing and selling products, working together with staff dispatched from Japan including myself; we put top priority on product quality. Our products are mainly used for the electric power, steel, metallurgical, petrochemical, and chemical industries as well as for railways and subways. With the growing environmental awareness, the demand for products for wind power generation has recently been increasing. Products for railroads in particular will be in great demand because both passenger lines and coal transportation lines are being rapidly constructed throughout the nation. We will continue to help improve the electric power infrastructure in developing China.

Yoshiaki UCHIDA (President)

Environment-friendly VCB : Vacuum circuit breaker using dry air

New plant inauguration ceremony

40.5kV C-GIS for Qinghai line

Corporate data

▼ **Address**
North Jiading Industrial District, Shanghai

▼ **Year of foundation**
2004

▼ **Capital**
US$4.5 million (as of the end of fiscal 2010)

▼ **Businesses**
Manufacture, sale, and after-sale service of medium-voltage switchgear

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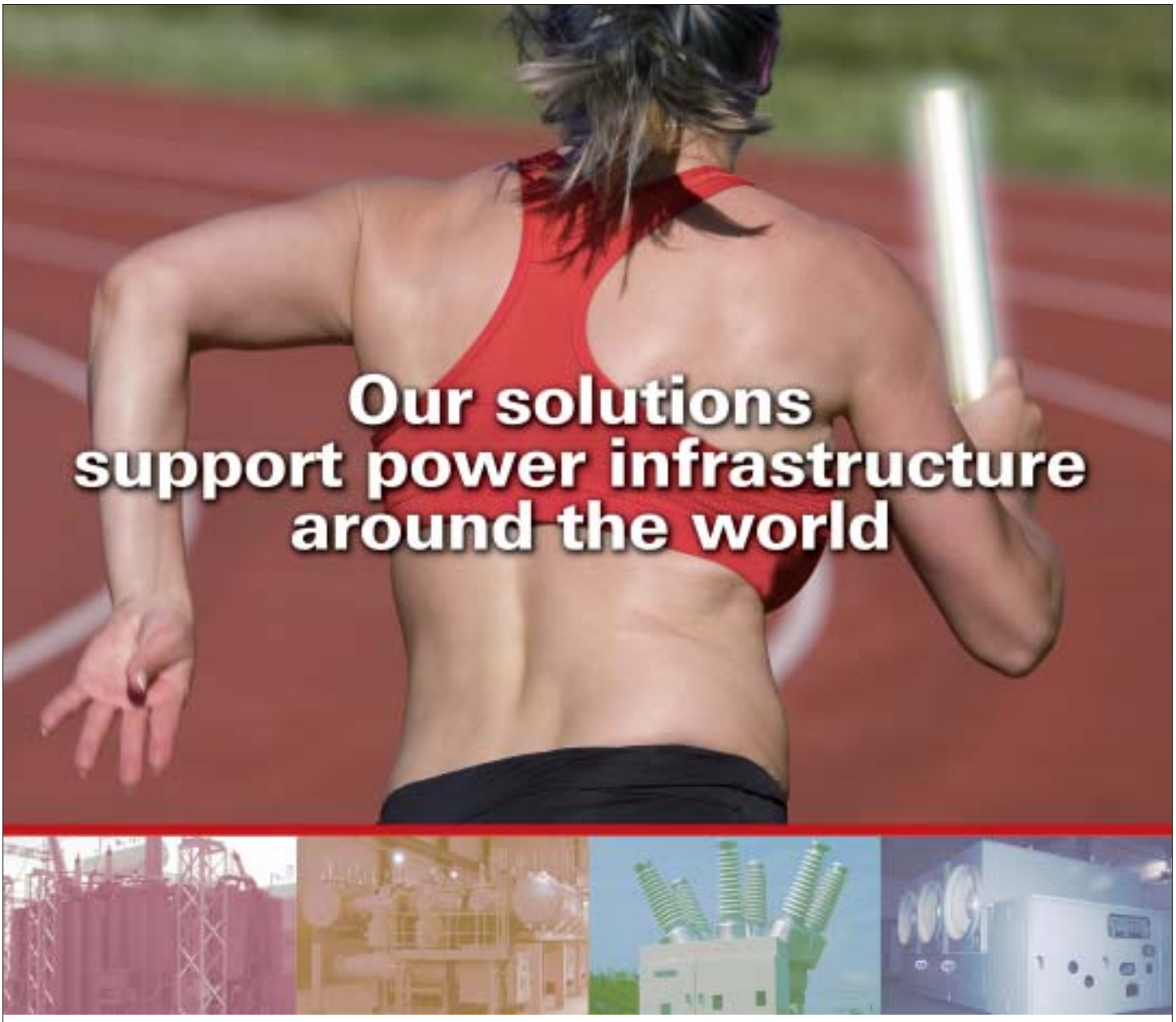

Japan AE Power Systems is committed to support stable supply of high quality electricity.
We provide a variety of transmission and distribution products and solutions
for power utilities, industrial facilities, railroad companies and many other users
throughout the world.
Our reliable, safe and environment-friendly products, such as transformers,
circuit breakers, switchgear and substation systems, as well as optimum solutions satisfy
the need of increasingly environment-conscious society.
We strive to help create smarter and better future
as an energy solution company.

HFMJÆPS

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