The Related Practices for the Design for Low Frequency Electric Arc Furnace

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Abstract: This paper expounds some application problems of low frequency electric arc furnace operation in industrial production. As a developing technique, low frequency power supply has been successfully utilized for smelting ferrochromium-iron, ferromanganese, ferrosilicon, industrial silicon metal and electrically-melted magnesium, and is becoming accepted by more and more people. Low frequency electric arc furnaces for industrial production have gone through both the trials of harmonic and the limits of electrode diameter and current-carrying capacity. Problems encountered have been either alleviated or overcome by the implementation of pertinent up-to-date technology.

1. PREFACE

In 1984, Russian scientists carried out research and experimentation on low frequency electric arc furnaces. In China, since that time the low frequency technique has been successfully utilized for smelting powder chromium ore, high carbon ferrochromium-iron, ferrosilicon, ferromanganese, electrically-melted magnesium, ferrosilicon-aluminum, silicon-aluminum-barium and industrial silicon metal. At present, as a piece of metallurgical equipment, the low frequency electric arc furnace has developed fast; see Table 1. The main reasons for this rapid development are as follows:

- When the frequency changed from 50Hz (or 60Hz) to 0.05Hz, the inductive reactance of the high current line decreased significantly, thereby power factor increased and energy was saved;
- Low frequency current has a stronger agitation function, that results in a more uniform furnace temperature distribution, shorter melting times, and higher output;
- More uniform electrode current, that results in lower electrode surface current density, thus promoting a lower electrode oxidation rate and a lower electrode consumption;
- Lower furnace "noise";
- Relatively easy furnace start-up and relatively easier day-to-day furnace operation.

Table 1. Low Frequency Ore-smelting Furnaces Developed by Xi´an Huaxing Electric Furnace Company Ltd.

Name of Producer and Location	Capacity (MVA)	Product	Quantity	Year
JINTIE, JINZHOU	5.0	Ferrochromium iron	1	1995
LANTIAN, ANSHAN	0.8	Electric melted magnesium	1	1998
HELANSHAN, NINGXIA	3.2	Ferrosilicon-aluminum Silicon-aluminum-barium	1	1998
HUINONG, NINGXIA	6.3	Ferrosilicon	2	1999
SANMING, FUJIAN	3.2	Industrial silicon metal	1	2000
HUTIE, HUNAN	5.0	Ferrochromium iron	2	2000
ZUNTIE, ZUNYI	3.5	Ferromanganese	1	2000
HEJIN, SHANXI	6.3	Ferrosilicon	2	2000
LONGHU, NINGXIA	6.3	Ferrosilicon	2	2000
DONGLIN, JILIN	6.3	Industrial silicon metal	1	2000

2. THE DESIGN OF LOW FREQUENCY DEVICES

Transformer

The design of the transformer for the low frequency devices is important. Generally speaking, the transformer of an ore-smelting furnace can be selected as the transformer of the low frequency device, consequently it is not necessary to select a significantly more expensive rectiformer.

Regardless of the number of windings, which may be three windings, four windings or six windings, the secondary winding of the transformer can be designed for low frequency devices. Years ago, a transformer having one secondary winding was successfully utilized in a low frequency device that was used for smelting electrically-melted magnesium. With the exception of energy savings, output increased, graphite electrode consumption decreased, and the rate of first grade magnesium production doubled.

In order to decrease heat generation and vibration of the cabinet, the main circuit of the low frequency power supply should be designed with what is known as "Same Phase Anti-Parallel Circuitry", and the transformer should have four secondary windings; see Figure 1.

2.2 Converter

The converter is the heart of low frequency device. The main circuit still uses thyristors because of their reliability and relatively low cost.

Thanks to their successful design by the engineers, the problem of current equalization for parallel thyristors has been resolved. Thus the reliability and stability of the thyristors have been greatly increased.

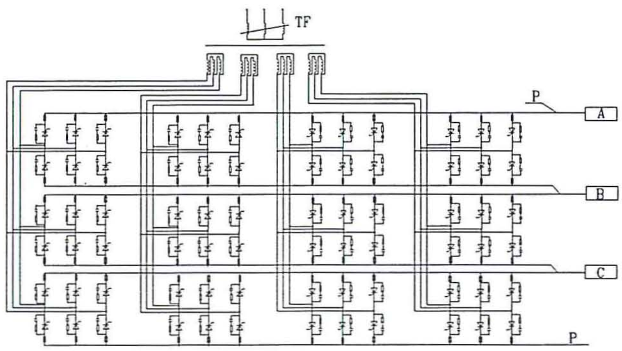

Figure 1

The problem of heat generation in the cabinets must be resolved. A water cooling system is necessary. The heat generated in the working thyristors can be removed in a controlled manner by the use of water flow meters to adjust water flow rate.

The converter control system consists of: a change frequency system, a current control system, a current measurement system, an electrode adjustment system, a trigger system, protection system, and a computer monitor system; see Figure 2.

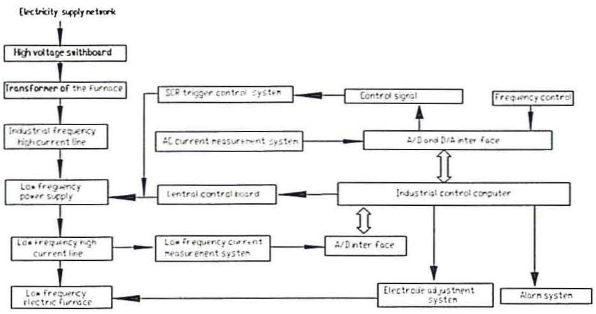

Fig .2

We may can see from the above figures that the electrical engineers have adopted the technique of "Same Phase Anti-Parallel Circuitry", thereby greatly decreasing magnetic field intensity and ferro-losses, while alleviating problems associated with the heat generation and vibration of the cabinets.

2.3 The Harmonic Filter

The converter makes harmonics in the electrical supply network. Consequently, it is necessary that a harmonic filter should be designed for large capacity electric furnaces.

The working fundamentals of a harmonic filter are associated with voltage resonance. When an N-order harmonic occurs in electric network: the filter generates voltage resonance and presents the lowest possible impedance to the N-order harmonic; the inductive reactance counteracts the capacitive reactance such that only harmonic resistance remains; consequently the N-order harmonic current is absorbed by the filter and does not flow to the electric network. For other order harmonic currents, the filter presents a relatively higher impedance and a relatively smaller current.

3. CONCLUSION AND PROSPECTS

Table 2. Comparison between Low Frequency and Industrial Frequency for Smelting 75% Ferrosilicon Alloy

Frequency	Apparent Power	Active Power	Cos(φ)	Secon-dary Current	Secon-dary Voltage	Operating Resistance of each	Electric Efficiency	Operation Time / Day	Electricity Consumption per ton	Output per Day

(Hz)	(MVA)	(MW)	(-)	(kA)	(V)	Phase (M)	(-)	(hour)	(kWh/t)	(t/da y)
50.0	6.3	5.29	0.84	34.9	105	1.3	0.89	23.6	9,000	13.8
0.03	6.3	5.8	0.92	36.0	98	1.3	0.87	23.6	8,300	16.5
0.05	6.68	6.15	0.92	38.5	98	1.2	0.867	23.6	8,300	17.4

Operational experience with low frequency electric furnace production of ferroalloys has demonstrated that this technique gives fine energy-savings and other technical and economical advantages. Comparison with industrial frequency electric arc furnaces shows:

Electric energy savings 5%
Electrode savings 35%
Power factor 0.9
Output increase 15%
Noise < 65dB

These advantages have led to the rapid development of low frequency power supply in China. In the future, low frequency power supply will develop from small and medium furnaces to large capacity electric furnaces.

REFERENCES

"Application of Thyristor Sources to Supply Ore-Smelting Electric Furnaces", I.P. Brukovsky, S.M. Nekhamin, V.L. Rozenberg, et alia, Electro-technika, 1984 No. 2, pp. 33-36.

2. USA Patent 4388108, "Melting Method of Ore-Smelting or Arc Steelmaking Electric Furnace and a Device for its Implementation", V.L. Rozenberg, I.P. Brukovsky, S.M.Nekhamin, et alia.

3. "The Design of Harmonic Filter", Hua kai (Xi'an Huaxing Electric Furnace Co. Ltd.

4. "The Converter Device of Low Frequency Ore-Smelting Furnaces", Li Zhichao (Xi'an Huaxing Electric Furnace Co. Ltd., Chen Xuaming (JILIN Ferroalloy Group Co. Ltd., Liu Huiming (Xi'an University of Architecture and Technology).

5. "Operational Advantages of Submerged Arc Furnaces Supplied with Low Frequency Power Supply", Li Zhichao and Liu Jiading (Xi'an Huaxing Electric Furnace Co. Ltd.