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RANCANG BANGUN TUNGKU BUSUR LISTRIK SATUFASE UNTUK PELEBURAN KONSENTRAT MANGANDAN BESI MENJADI FEROMANGAN

SingLe-Phased ELectric Arc Furnace Design for SmeLting Manganese andIron Concentrates Into Ferromanganese

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SARI

Telah dilakukan rancang bangun tungku busur listrik satu fase untuk melebur konsentrat mangan, konsentrat besi, dan sedikit skrep besi menjadi logam paduan feromangan berkapasitas 10 kg. Tungku dirancang dengan mempertimbangkan sistem geometri, elektrik dan sistem aktuator hidroliknya. Rancangan tungku berbentuk cawan silindris dengan diameter bagian dalam 15 cm dan tinggi selubung bagian dalamnya 22 cm. Suplai daya yang diperlukan sebesar 35 KVA. Energi yang dibutuhkan dalam proses peleburan sebesar 32,016 KJ. Dengan dimensi diameter elektroda grafit sekitar 2,7 cm, maka panas akan terjadi saat busur listrik berdekatan dengan bahan baku/konsentrat. Panas yang ditimbulkan mampu melebur konsentrat mangan, konsentrat besi dan skrep besi menjadi lelehan logam paduan feromangan. Ujicoba tungku tersebut menghasilkan komposisi produk logam paduan feromangan berkadar Mn ≥ 70% dan Fe = 14 - 16%. Oleh karena itu, model rancangan tungku busur listrik ini layak diperbesar skalanya dengan mempertimbangkan konstruksi geometrik, daya dan aktuator hidrolik yang digunakan.

Kata kunci: rancang bangun, tungku busur listrik satu fase, feromangan, konsentrat mangan, konsentrat besi

ABSTRACT

A single-phase electric arc furnace (capacity 10 kg) has been design to be used for smelting the concentrates of manga- nese, iron and a small amount of iron scrap into ferromanganese alloy. The furnace was designed by considering the geometry, electrical system and hydraulic actuator system in the form of a cylindrical cup with inner diameter 15cmand 22cm height. The power requirement is 35 KVA, while the energy requirement for smelting and melting action is 32.016KJ. By setting the graphite electrode diameter of about 2.7 cm,the heat would occur as the electric arc is adjacent to the raw materials. The generated heat would be proper to smelt manganese and iron concentrates as well as ironscrap into melted ferromanganese alloy. The testing operational of the designed furnace produced ferromanganese alloy containing Mn ≥ 70 % and Fe = 14 - 16 %. Therefore, the present model of the designed electric-arc furnace might reasonably scaled-up by considering its geometric construction, power and hydraulic actuator.

Keywords: single-phase electric arc furnace design, ferromanganese, manganese concentrate, iron concentrate processes

MDPI

Article

Development of an Electric Arc Furnace Simulator Based on a Comprehensive Dynamic Process Model

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Abstract: A simulator and an algorithm for the automatic creation of operation charts based on process conditions were developed on the basis of an existing comprehensive electric arc furnace process model. The simulator allows direct user input and real-time display of results during the simulation, making it usable for training and teaching of electric arc furnace operators. The automatic control feature offers a quick and automated evaluation of a large number of scenarios or changes inprocess conditions, raw materials, or equipment used. The operation chart is adjusted automaticallyto give comparable conditions at tapping and allows the assessment of the necessary changes in the operating strategy as well as their effect on productivity, energy, and resource consumption, along with process emissions.

Keywords: electric arc furnace; simulation; process model; steelmaking

1. Introduction

The electric arc furnace (EAF) process is the main process for recycling of ferrous scrap [1] and the second most important steelmaking process route in terms of global steel production [2]. EAF processmodels have proven to be useful for improving process understanding and control as well as resource and energy efficiency by providing information that cannot be measured directly during the process due to the extreme conditions inside the furnace. Numerous models have been developed using different approaches both for the complete process as well as local phenomena or single process phases. However, few simulators allow for real-time manipulation of simulations by the user. Logar et al. [3] describe a simulator based on their process model and the World Steel Association provides an online EAF simulator on their website [4]. The simulator of Logar et al. [3] is based on a previously developed process model considering detailed heat transfer [5,6] and thermochemical equations [7] as well as an electrical model [8], whereas the World Steel Association gives only limited information about the workings of their model [9]. Other published models run simulations based on predetermined input data and although they can be used to study different scenarios, they do not adapt to current simulation results or user inputs.

In order simulate the process independent of plant data and cover extreme cases that may occurwith unusual user input, a comprehensive mechanistic modelling approach is necessary. Several suchmodels are available in the literature such as those of Bekker et al. [10–12] and MacRosty et al. [13–15] who introduced some of the simplifications and assumptions that Logar et al. based their model on, as well as several others that have been published with a varying degree of detail [16–31]. Both Meier et al. [32–37] and Fathi et al. [38] have published models developed on the basis of the

Modeling and Control of an Electric Arc Furnace

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***Abstract*— Model Based Predictive Control is a class of computer algorithms that explicitly use a process model to predictfuture plant outputs and compute an appropriate control action through on-line optimization of a cost objective over a futurehorizon, subject to various constraints. The cost function is defined in terms of the tracking error (the difference between the predicted output and set-point). Using this scheme, many differentMBPC algorithms have been proposed in the literature. This paper presents an adaptive-predictive control algorithm, which uses on-line simulation and rule-based control. The algorithm is applied to an electrode position system of an electric arc furnace. Electric arc furnaces are commonly used in steelmaking and in smelting of nonferrous metals. To obtain the electric arc, usually there are used three graphite electrodes. The power level depends by the positions of the electrodes. As a result, the realization of a competitive control system is very important because it led to reduction of the energy consumption, pollution, and increases the safety of the process.**

I. Introduction

Model Based Predictive Control (MBPC) designates a very ample range of control methods that make an explicit use of a model of the process to obtain the control signal by minimizingan objective function. The main ideas of MBPC are basically:

-explicit use of a model to predict the process output in the future;

-on line optimization of a cost objective function over a future horizon;

-receding strategy, so that at each instant, the horizon is displaced towards the future, which involves the application of the first control signal of the sequence calculated at each step.

Usually, the cost function is defined by using the output prediction error relative to the system setpoint and the weighted control signal, which can lead to a quadratic function as follows:

Performance of MBPC could become unacceptable due to a very inaccurate model, thus requiring a more accurate model. This task is an instance of closed-loop identification and adaptive control. The difficulty of closed-loop identification is that the input of process to be identified is not directly selected by the designer but ultimately by the feedback controller.

The popularity of model-based predictive control is partially explained by the fact that it uses traditional dynamic process models which are usually available for design and/or simulation purposes. At the same time, model-based predictive control is being criticized by control engineers because of its lack or weakness of theoretical background, having no guarantee of convergence, stability, robustness, etc. in the general case [1]. The extension of linear MBPC to nonlinear processes is straightforward at least conceptually. But there exists some difficulties [2]: the availability of nonlinear models due to the lack of identification techniques for nonlinear processes, the computational complexities, the lack of stability and robustness results. A solution to increase the performances is to use multiple models [3].

$$J(N_1,N_2)=\sum_{j=N_1}^{N_2}\left[y(t+j)-y_r(t+j)\right]^2+\sum_{j=1}^{N_u}\rho(j)\left[\Delta u(t+j-1)\right]^2 \quad (1)$$

where y[.] is the predicted values of output signal, y_r[.] is the future setpoint, u[.] is the future control signal, N_1 is the minimum predicted horizon, N_2 is the maximum predicted horizon, N_u is the command horizon, ρ(j) is a control-weighting sequence.

In the metallurgic industry for the melting of the scrap or other metals it is used the electric arc furnace (EAF). The electric arc allows to obtain high temperatures necessary to melt or/and to realize some chemical reactions (fig. 1). To obtain the electric arc, usually there are used three graphite electrodes which are supplied by a three-phase power transformer that has in the primer 20-30 KV respective 100- 800V in the secondary.

The electric power (10…100 MW) depends by the length of the arc which can be controlled using an efficient hydraulic control system of electrode position. The circuit closes through the metal mass that will be molten. The principle needs a very high-energy consumption, which implies a very efficient control system to reduce as much as possible energy consumption. Many times the weight of the electrodes is very high; it could reach tenth of tons. The hydraulic control system becomes complex. The acceleration and deceleration imposed for the electrodes must ensure variable velocities from the hydraulic control system with the aim of avoiding damage of the resistance structure.

The electric arc appears when the electrodes are near the metal mass. To close the circuit, the electric arc must to appear at least between two electrodes and the metal mass. Usually the

STUDI PEMODELAN DAN PENGENDALIAN *ELECTRIC ARC FURNACE* (*EAF*)DI PT. BARATA INDONESIA (Persero)

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Abstrak :

Kebutuhan akan penggunaan logam baja saat ini mengalami perkembangan seiring dengan pertumbuhan pada berbagai bidang industri. Dengan demikian diperlukan proses pembuatan ataupun peleburan yang mengasilkan logam sesuai dengan keperluan aplikasi dalam pemakaiannya, dalam hal kekuatan, kekerasan, kekuatan lelah, ketahanan korosi dan sebagainya, sehingga dalam pemakaiannya akan memberikan hasil yang paling optimal. Namun pada proses tersebut biasanya masih membutuhkan pengendalian daya yang cukup besar, sehingga proses ini dirasa kurang efisien. Pengefisienan daya ini dapat diatasi dengan memodelkan dan mengendalikan Electric Arc Furnace (EAF). EAF merupakan inti dari proses peleburan logam baja yang dikenal dengan mini-mills. Maka dalam tugas akhir ini dibuat simulasi pemodelan dan pengendalian pada EAF menggunakan software Matlab, dimana pengontrolnya menggunakan sistem Open-Loop dan Close-Loop sehingga didapatkan suatu pemodelan dan pengendalian EAF yang dinamis dengan pengambilan sampel di PT. Barata Indonesia (Persero) Gresik. Memodelkan dan mengendalikan EAF dengan sistem Close-Loop arus yang dihasilkan dan daya listrik yang dikonsumsi lebih efisien 69.82% dibandingkan dengan sistem Open-Loop.

1. PENDAHULUAN

Masalah kualitas daya listrik pada sistem kelistrikan industri merupakan hal yang penting untuk diketahui. Sebab pada sebuah industri khususnya industri peleburan besi baja, masalah kualitas daya listrik ini memegang peranan penting dalam menentukan keberadaan industri atau pabrik tersebut.

Ada beberapa faktor yang mempengaruhi kualitas daya listrik, antara lain: ketidakseimbangan tegangan, gangguan tegangan, faktor daya dan hamonisa. Di industry peleburan baja, kerlip cahaya (*light flicker*) menjadi suatu masalah yang *signifikan* sebab di pabrik peleburan baja terdapat tanur busur listrik yang merupakan salah satu sumber beban fluktuatif

Electric Arc Furnace (EAF) atau juga disebut tanur busur listrik adalah bagian utama dari sebuah pabrik peleburan baja dalam melakukan peleburan baja. *EAF* atau tanur busur listrik biasanya terdiri tiga buah batang elektroda besar yang biasanya terbuat dari *graphite*. Untuk melakukan peleburan besi dan baja, dilakukan pembenturan *electric arc* (busur listrik) antara elektroda dengan baja yang ada dalam sebuah wadah besar.

Dengan arus yang sedemikian besar sudah pasti sebuah *EAF* akan menyerap daya yang besar pula, sehinggaproses ini dirasa kurang efisien. Hal ini pasti akan sangat berpengaruh terhadap kestabilan sistem berupa kerlip cahaya *(light fliker).* Oleh karena itu memodelkan dan mengendalikan *EAF* bertujuan untuk mendapatkan pengendalian daya yang dibutuhkan menjadi se-efisien mungkin, tetapi tetap memberikan hasil yang optimal.

2. KUALITAS DAYA LISTRIK

2.1 PENGERTIAN KUALITAS DAYA LISTRIK

Kualitas daya listrik memiliki beberapa definisi,tergantung dari sisi pengamatnya. Bagi pelanggan, kualitasdaya listrik mereka definisikan sebagai keandalan sistemtenaga listrik atau energi listrik yang menyatakan 99,9%sistem kelistrikan tersebut dapat diandalkan. Sedangkan bagipara produsen peralatan listrik, mereka mendefinisikankualitas daya listrik sebagai karakteristik suplai tenaga listrik dimana dapat menyuplai beban yang mereka hasilkansehingga berfungsi dengan baik. Secara umum, kualitasdaya listrik dapat diartikan sebagai segala macampermasalahan yang berhubungan dengan tegangan, arus, maupun frekuensi yang dapat menyebabkan kegagalansistem maupun kesalahan operasional hingga sisi pelanggan.Kualitas daya listrik pada kenyataannya berhubungan dengan gangguan tegangan (*voltagedisturbance*), harmonisa (*harmonics*), faktor daya (*power factor*) dan kompensasi daya reaktif (*reactive power compensation*).

2.2 GANGGUAN TEGANGAN (VOLTAGEDISTURBANCES)

Gangguan tegangan berpengaruh langsung pada suplai daya listrik, oleh karena itu masalah gangguan tegangan ini harus segera diatasi.Gangguan tegangan antaralain disebabkan oleh beban-beban yang menyebababkan aliran arus menjadi sangat cepat sehingga memungkinkan terjadinya variasi tegangan. IEEE Recomended Practices Std 1159, mengelompokkan gangguan tegangan sebagai berikut:Transient, Short-duration Variation, Long-duration

MENGURANGI GANGGUAN KEDIP TEGANGANPADA PERALATAN INDUSTRI

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ABSTRACT

Voltage flicker disturbance is one form of power quality disturbances that are considered most likely to cause losses due to the disruption of the operation of various processes in the industry, especially industries using control equipment, modern power electronics and data processing, which are generally very sensitive to voltage variations. Losses incurred as a result of the disorder is relatively large, including the form of damage to the product, damage to the means of production and cessation of production. This disorder usually caused by the occurrence of the interference of the transmission and distribution networks,as well as the installation of the consumer or industry itself. Therefore, the discussion and understanding of the characteristics of voltage flicker disturbances and sensitivity of industrial equipment for the disorder, which is the issue of this writing, expected to be useful in determining the electrical power quality criteria can be agreed well by the corporate who manage the electricity in Indonesia and industrial or manufacturing as the users.

Keywords: *voltage dip, voltage variation, sensitivity.*

ABSTRAK

Gangguan kedip tegangan adalah salah satu bentuk gangguan kualitas tenaga listrik yang dianggap paling sering menyebabkan kerugian akibat terganggunya pengoperasian berbagai proses di industri, khususnya industri yang menggunakan peralatan kontrol, elektronika daya modern dan pengolahan data, yang umumnya sangat sensitif terhadap variasi tegangan. Kerugian yang timbul akibat gangguan tersebut relatif cukup besar, diantaranya berupa kerusakan produk, kerusakan alat-alat produksi bahkan terhentinya produksi. Gangguan ini umumnya disebabkan oleh terjadinya gangguan pada jaringantransmisi dan distribusi, maupun pada instalasi dari konsumen atau industri itu sendiri. Oleh karenanya, pembahasan dan pemahaman tentang karateristik gangguan kedip tegangan dan sensitivitas peralatan industri terhadap gangguan tersebut, yang merupakan inti dari penulisan ini, diharapkan dapat bermanfaat dalam menentukan kriteria kualitas tenaga listrik yang dapat disepakati baik oleh pengelola kelistrikan di Indonesia, maupun industri atau pabrikan sebagai pengguna tenaga listrik tersebut.

Kata kunci: *kedip tegangan, variasi tegangan, sensitivitas.*