 ISBN: 978-93-86171-70-2

BLAST FURNACE-8 WITH FLYWHEEL AND VAM FOR EFFECTIVE WASTE HEAT RECOVERY

Ankita Thakur[1], Ashraf Jafri[2]

[1] *Department of Electrical and Electronics Engineering, Chhatrapati Shivaji Institute of Technology, Durg, CSVTU Bhilai, Chhattisgarh, (India)*

[2] *Department of Electrical and Electronics Engineering, Chhatrapati Shivaji Institute of Technology, Durg, CSVTU Bhilai, Chhattisgarh, (India)*

ABSTRACT

Nowadays power system is facing dramatic changes and operational requirements regarding electric power as a result deregulation in power system has occurred. The growth in continuous electric load and high regional power transfer in a huge interconnected system leads us to a complex and less secure operational power system. The generation, distribution and transmission of power facilities of growing demand is not able to meet the new demands as per economic, environmental, technical and governmental regulation at the same time the growing demand of electronic loads have made quality of power system an critical issue. So now power system engineer needs more reliable and accurate solution of this challenging phase of our power system with more flexible and controllable manner.

Keywords: Blast furnace (bf), flywheel, heat recovery, top recovery turbine (TRT), vapour absorption machine (VAM).

I.INTRODUCTION

The occurrence of power system disturbances, synchronous generator is not always able to respond quickly enough to make system stable. If control of high-speed reactive power is available, generator dropping or load shedding may be avoided during those disturbance hours.

Recent development in energy storage power electronic technologies is making things easier. Storage technologies include batteries, flywheels, superconducting energy storage system and ultra capacitor. All these technologies were initially envisioned for large-scale load leveling. But energy storage is nowadays seen more as a tool to enhance power system stability and power transfer and improves power quality of the power system. A huge amount of flue gas is being generated at the top of the furnace. With the help of turbine that flue gas is being utilized and a amount of energy is then generated through turbine, but the fluctuation of gas at the top of the blast furnace is responsible for the fluctuation of power generated through turbine. If reduction in fluctuation of top pressure of the blast furnace is maintained then the power quality of power generated through turbine can be done. Proposing equipment for the reduction of the fluctuation is main object of this paper. Meanwhile selecting flywheel for the reduction of the fluctuation of top pressure of the blast furnace is proposed.

 ISBN: 978-93-86171-70-2

II. FLYWHEEL

Flywheels are used to store energy for power system, when flywheel is coupled with an electric machine. Generally power convertors are used to drive the electric machine to operate in a wider range. Now the stored energy depends on the moment of inertia of a rotor and the square of the rotational velocity of a flywheel. And moment of inertia (I) depends on the radius, mass, height and length of the rotor. Energy is then transferred to the flywheel when the machine is in the mode of operation of motor, and charging the energy storage device. Eventually flywheel is discharged when electric machine regenerates through the drive or slowing the flywheel.

The capacity of energy storage of flywheel can be improved either by accelerating or increasing the moment of inertia of the flywheel.

Two strategies have been utilized in the advancement of the flywheel for power applications. Option one is to increase the inertia while using a steel mass with a large radius, with rotational velocity approximately 10,000 rpm. A standard motor and power electronic drive can be used as power conversion for this type of designs is available as uninterruptible power supply (UP’s).

Option second is to produce flywheel with a lightweight rotor running at very high rotational velocity i.e. up to 100,000 rpm. This approach is concept and light weight energy storage device. Flywheel resist changes with their rotational speed, which helps the rotation of the shaft when a torque of fluctuation is exerted on it, by its power source such as piston-based engine, when an intermittent load is placed on it. Flywheel are used to produce very high power pulses for experiments, where drawing the power from the public network would produce spikes. Modern technology has enabled as a new application for the new equipment flywheel, in advanced flywheel energy storage system. The flywheel energy storage system stores energy in the form of kinetic energy. As hot flue rotates flywheel and energy is being stored in the batteries, and this energy is again feed back to the grid at the time of power on demand and an active power would be supplied to the grid.

III. INDENTATIONS AND EQUATIONS

A. Energy Storage System:

The most important type of energy storage system for practical application of the proposed method is equalizing the output power of a TRT with stochastic nature of the input of the turbine are secondary electrochemical cells can flywheel.

Above all the advantages of the flywheel as compared to the electrochemical cells lead acid and lithium-ion batteries. They contain constant value of energetic capacity in the range of temperature -35^0c to $+40^0$c, covering all weather conditions on yearly basis and huge amount of charging and discharging cycle reaching mllions life span of 15-20 years and short duration of storage charging approxing the discharge time with the rated power. High charging rate enables the use of flue energy even in case of quick variation, no need of using faster energy storage devices such as energetic buffers. The kinetic energy storage system is characterized by the high efficiency from the range of 80%-86%. It should be noticed that it requires smaller space, a close setup of group of modules in a container which is ready for transportation to another location.

The feature of the kinetic energy storage system, is that it might be considered as a fault as compared to accumulator batteries have lower energy density in case of lead-acid batteries from the range of 50Wh/L to

 ISBN: 978-93-86171-70-2

100Wh/L, while lithium-ions are from 200Wh/L to 350Wh/L. another fault is that due to high degree of self-discharging which is several percent per hour. Nevertheless, these feature are not decisive for blast furnace flue gas, TRT system and the electric power grid, however storage is not required to characterized by large energetic storage capacity and charging-discharging process lasts below 1-hr usually not more then twenty minutes. The investment amount of flywheel, converted to unit power or capacity of storage is several times higher than that of the lead-acid or lithium-ion batteries. Hence, economically use of such system must be censed as their fault of the technology of kinetic storage.

$$W_{rot} = (1/2).J.w^2$$

Where the energy, W_{rot} stores rotational energy

- **Kinetic energy-**

$$J = m.r^2$$

Where J is said to be mass moment of inertia,

The amount stored energy in rotational mass can be varied by varying w. It can also be varied by varying J. As seen above J can we varied square of the radius i.e. r. Therefore, by varying J can be controlled and hence kinetic energy w_{rot}.

- **Angular momentum-**

$$L = J.w = m.r^2.w$$

The angular momentum, L describes the kinetic energy is retained in the rotational system.

As angular momentum changes, a torque T results kinetic energy, W_{rot} remains constant.

$$T = Dl/Dt$$

As the large torque can be achieved as if r changes, as L is a function of r^2.

- **Flywheel system-**

$$W_{tr} = F.s$$

As the moving object certain distance, s, requires a force F, then energy W_{tr} is produced.

$$F_{fwcf} = m_{fw}.R_{var}.w_{rot}^2$$

The centrifugal force is F_{fwcf}, in the flywheel system, where R_{var} is the distance between the weight and the center of the rotor.

$$W_{tr} = m_{fw}.\{(R_{fwmax} + R_{fwmin}).w^2/2\}.(R_{fwmax} - R_{fwmin})$$

Hence, moving the weight in the flywheel against the centrifugal force from the largest radius, R_{fw_max}, to the smallest radius, R_{fw_min}, which is translation energy.

IV. VAPOUR ABSORTION MACHINE

As shown in figure below after using flue gas for generating power the amount of hot flue gas is still remand. So here we are again utilizing those hot flue gas for air conditioning process such as vapour absorption machine.

 ISBN: 978-93-86171-70-2

Waste heat is heat, which can be further used for generating necessary things. Dumping it into the environment is totally wasting heat energy. His essential quantity of heat can be recycled in the process. Strategies for how o recover this heat depends on the particular temperature of the waste heat gases and their economy involved. Large quantity of hot flue gas is generated in the process of blast furnace, after the whole process and after generating electrical power the rest energy can be recovered through VAM. If any amount of waste heat is recovered in this process it will be directly reduce the amount of primary fuel used in the process. And the energy lost in waste gases can be fully recovered. Losses can be recovered by adopting such a suitable measures.

Usually higher the temperature may cause higher quantity and higher cost to recover heat. There should be some useful measures of the recovered heat. The main objective of this work is to recover the waste heat available after use of flue gas to run vapour absorption refrigeration system this process replacing Freon-12 refrigerant which is main cause of ozone layer depilation and to reduce temperature of gas emission in the atmosphere which meanwhile causes global warming.

In order to run li-br VAM is main focus of heat recovery process, which is having a cooling capacity of 70 TR. Temperature of the blast furnace flue gas after process is very low which is 50^0C. As the temperature available is very low compared to the other plants. Only single set of VAM system does not requires much temperature and works on the range of temperature of 0^0C- 120^0C. For producing 70TR, 350 KW of heat is supplied for generator of the VAM so we design multi-pass to waste heat exchanger for recovering waste heat from the hot flue gas of the turbine for air conditioning effect.

- **Heat to be supplied to the generator of VAM**

The supplied heat to the generator of VAM can be found using this equation.

$$COP = Q_E/Q_G$$

Where Q_G is the supplied heat to the VAM generator and Q_E is the absorbed heat in the evaporator and COP is the coefficient of performance.

- **Outlet temperature of flue gas**

Through this equation the outlet temperature of the flue gas is found out.

$$Q = mC_P.T = Mc_P(T_{IN}-T_{OUT})$$

Where Q is said to be heat transferred from the flue gas to the water, m is mass of rate of flow of flue gas, C_P is specific heat of flue gas, T_{IN} is the inlet temperature of the flue gas and T_{OUT} is the flue gas outlet temperature.

- **Logarithmic mean temperature difference(LMTD)**

The another important step is fiding LMTD of the heat exchanger, which can b found out by this equation

$$LMTD = \Delta Tm = \Delta T_i-\Delta T_e/(\ln.\Delta T_i/\Delta T_e)$$

Where,

$$\Delta T_i = T_{h1} - T_{c2}$$

$$\Delta T_e = T_{h2} - T_{c1}$$

Here T_{h1} and T_{h2} are inlet and outlet temperature of the flue gas and T_{C1} and T_{c2} are values of the water.

 ISBN: 978-93-86171-70-2

- **Surface area of the heat exchanger**

By using this equation area of the heat exchanger is found out.

Heat transfer, $Q = UFA\Delta T_m$

Where U is the heat transfer coefficient, in $W/m^2\ ^0C$, A is the surface of heat exchanger in m^2 and ΔT_m is the LMTD in ^0C and F is correction factor.

- **Mass Flow Rate of Water through Heat Exchanger**

$Q = m\ Cpw\Delta T = m\ Cpw(Tout - Tin)$

Where m is mass flow rate of the water in Kg/sec, Q is the heat transfer in KW, C_{pw} is the capacity of specific heat of water, T_{In} is the temperature of inlet water in ^0C and T_{out} is the temperature of outlet water in ^0C.

- **Number of Tubes, Diameter and Length of the Pipe**

$A = \pi dLn$

Where d is the diameter of the n tubes, L is the length of the single tube.

Where,

$D = 10cm$

$L = 2m$

$N = 11$

- **Velocity of water through the pipes**

$m = \rho AcV$

Where ρ is the density of water in Kg/m^3, A_C is the cross sectional area of the heat exchanger, in m^2 and V is the velocity of water through heat exchanger in m/s

- **Energy saving**

Power required for operating VCM =78.2985 KW

Power required for operating VAM = 2% of VCM =1.566 KW

Total Power Saved = 78.2985 – 1.566 = 76.732 KW

Energy saved if air-conditioner works 12 hours per day = 76.732 × 12 = 920.784 KWhr = 920.784 Units/day.

V. FIGURES AND TABLES

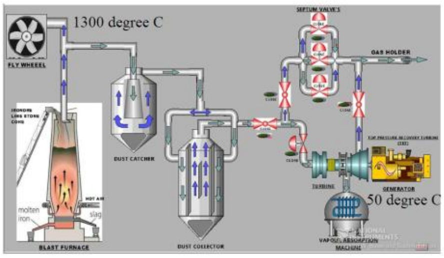

Figure 1 Blast frnace-8 with Flywheel and VAM system.

 ISBN: 978-93-86171-70-2

VI. CONCLUSION

A consistent and constant inlet of flywheel and VAM can help recovering waste heat energy throughout the process. And the fluctuation of blast furnace gas inlet pressure may adversely affect the power generation but by using flywheel these incidence would occur rarely. As It will provide stored energy at the time of peak demand of power in the form of active power in the grid and hence fluctuation could hardly affect the generated power output. Although adopting these alternatives heat recovery process may help us moving towards green energy plus reducing primary fuel conservation during process.

VII.ACKNOWLEDGEMENTS

This research was supported by the Bhilai Steel Plant, Bhilai, Chhattisgarh. We thank our colleagues from chhatrapati Shivaji Institute of Technology, Durg who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretation/conclusion of this paper.

REFERENCES

Journal Papers:

[1] *Flue gas low temperature heat recovery system for air conditioning*, nirmal sajan[1], ruben philip[2], vinayak suresh[3],Vishnu m[4] , Mathew john [5].

[2] *Utilizing Waste Heat for Steam Generation Within an Integrated Steelworks: A Methodology for Power Generation and CO2 Reduction*, *Chris Williams, Anthony Griffiths, Tim O'Doherty and Anthony Giles.*

[3] *Optimization of Material Procurement Plan – A Database Oriented Decision Support System*, Shyamalesh Khan1 and Sanjay Kumar2, *Submitted in April 2011; Accepted in January 2012.*

[4] *Choice of technological regimes of a blast furnace operation with injection of hot reducing gases*, A.Babich, H.W.Gudenau, A.Formosol, K.Mavrommatis.

[5] *Optimization of Top Gas Recycling Conditions under High Oxygen Enrichment in the Blast Furnace*, Hannu HELLE, Mikko HELLE, Henrik SAXÉN and Frank PETTERSSON, Thermal and Flow Engineering Laboratory, Åbo Akademi University, Biskopsgatan 8, FI-20500 Åbo, Finland. (*Received on November 4, 2009; accepted on February 19, 2010*)

[6] *Ironmaking Technologies Contributing to the Steel Industry in the 21st Century Akira Maki** and Tatsuro Ariyama*** General Manager, Ironmaking Technology Development Dept., Steel Technical Center** General Manager, Dr., Ironmaking Research Dept., Materials & Processing Research Center.

[7] *A Blast Furnace Model to Optimize the Burden Distribution*, G. Danloy (1), J. Mignon (1), R. Munnix (1), G. Dauwels (2), L. Bonte (2)(1) Centre for Research in Metallurgy (CRM), Liège, Belgium, www.crm-eur.com(2) Sidmar, Gent, Belgium, www.sidmar.be.

[8] *Process Simulation and Control Optimization of a Blast Furnace*, Using Classical Thermodynamics Combined to a Direct Search, Algorithm JEAN-PHILIPPE HARVEY and AI¨MEN E.GHERIBI.

[9] *Comparative performance evaluation of blast furnace ame temperature prediction using articial intelligence and statistical methods,* Yasin TUNC_KAYA1;_, Etem K☐OKL☐UKAYA2 1C_ al_k Enerji, Ankara, Turkey, 2 Department of Electrical and Electronics Engineering, Faculty of Engineering, Sakarya

University, Sakarya, Turkey.

[10] *Failure Analysis for Blast Furnace Using What If Analysis*, R.Suresh1, M. Rajesh Kumar2, K. Tamil selvam3 Department Mechanical Engineering, Anna University, Knowledge institute of technology Salem, Tamilnadu, India1, 2,,3

[11] *Energy Storage Systems for Advanced Power Applications*, Paulo f. rbeiro, senor member, IEEE, brian k. Johnson,PAULO F. RIBEIRO, SENIOR MEMBER, IEEE, BRIAN K. JOHNSON, IEEE, proceedings of the IEEE, *vol. 89, NO. 12*, December 2001.

[12] *Study on High Temperature Superconducting Magnetic Bearing for 10 kWh Flywheel Energy Storage System*, Shigeo Nagaya, Naoj i Kashima, Masaharu Minami, Hiroshi Kawashima and Shigeru Unisuga, IEEE transactions on applied superconductivity , *vol. 11, no. I*, March 2001.

[13] *A functional approach for studying technological progress: Extension to energy technology*, Heebyung Koh a,1, Christopher L. Magee b, a. Massachusetts Institute of Technology, 77 Massachusetts Avenue, Building, NE20-392C, Cambridge, MA 02139-4307, United States, b. Massachusetts Institute of Technology, 77 Massachusetts Avenue, Building, NE20-392B, Cambridge, MA 02139-4307, United States Received 27 March 2007; accepted 30 May 2007.

[14] *Energy storage systems—Characteristics and comparisons*, H. Ibrahima,b,_, A. Ilincaa, J. Perronb, a Wind Energy Research Laboratory (WERL), Universite´ du Que´bec a` Rimouski, 300 alle´e des Ursulines, Que´. Canada G5L 3A1, b. Anti Icing Materials International Laboratory (AMIL), Universite´ du Que´bec a` Chicoutimi, 555 boulevard de l'Universite´, Que´. Canada G7H 2B1 Received 1 December 2006; accepted 5 January 2007.

[15] *Thermodynamic characteristics of a novel supercritical compressed air energy storage system*, Huan Guo a,b, Yujie Xu a, Haisheng Chen a, Xuezhi Zhou a, a Institute of Engineering Thermophysics, Chinese Academy of Sciences, Beijing 100190, China, b. University of Chinese Academy of Sciences, Beijing 100049, China Energy Conversion and Management 115 (2016) 167–177.

[16] *Conceptual System Design of a 5 **MWh/100** MW, Superconducting Flywheel Energy Storage Plant for Power Utility Applications*, Hans J. Bomemann, Forschungszentrum Karlsruhe GmbH, INFP, P. 0. Box 3640, 76021 Karlsruhe, Germany, Michael Sander, Gesellschaft fur Angewandte Supraleitung GdbR, c/o Forschungszentrum Karlsruhe GmbH, 76021 Karlsruhe, Germany IEEE, transations on applied superconductivity, *vol. 7, no. 2*, june 1997.

[17] *Design and construction of a LiBr–water absorption machine*, G.A. Florides a, S.A. Kalogirou a,*, S.A. Tassou b, L.C. Wrobel b, a Department of Mechanical Engineering, Higher Technical, Institute, P.O. Box 20423, Nicosia 2152, Cyprus, b Department of Mechanical Engineering, Brunel University, Uxbridge, Middlesex, UB8 3PH, UK, Received 22 July 2002; accepted 11 December 2002.

[18] *Second law comparison of single effect and double effect vapour, absorption refrigeration systems*, Rabah Gomri * Engineering Faculty, Department of Genie Climatique, Constantine University, 25000 Constantine, AlgeriaEnergy Conversion and Management 50 (2009).

[19] *Thermoeconomic optimization of a single effect water/LiBr vapour absorption refrigeration system*, R.D. Misra, P.K. Sahoo*, S. Sahoo, A. Gupta, Mechanical and Industrial Engineering Department, Indian

Institute of Technology Roorkee, Roorkee, 247 667, India, Received 30 November 2001; received in revised form 5 September 2002; accepted 10 September 2002.

[20] *Modeling and Analysis of a Flywheel Energy Storage System for Voltage Sag Correction*, Satish Samineni, *Member, IEEE*, Brian K. Johnson, *Member, IEEE*, Herbert L. Hess, *Senior Member, IEEE*, and Joseph D. Law, *Member, IEEE*, IEEE transactions on industry applications, *vol. 42, no. 1*, January/February 2006.

[21] *Key Manufacturing Technology & Equipment for Energy Saving and Emissions Reduction in Mechanical Equipment Industry*, Zhongde Shan1,#, Shaoyan Qin1, Qian Liu1, and Feng Liu1, international journal of precision engineering and manufacturing, *vol. 13, no. 7*, pp.1095-1100 july 2012/1095.

[22] *A review of absorption refrigeration technologies*, Pongsid Srikhirin *, Satha Aphornratana, Supachart Chungpaibulpatana Mechanical Engineering Program, Sirindhorn International Institute of Technology, Thammasat, University, PO Box 22 Thammasat Rangsit Post Office, Patumthani 12121, Thailand, Received 11 January 2001; accepted 12 February 2001.

[23] *Innovations in vapour-absorption cycles*, Shenyi Wu, Ian W. Eames*. School of the Built Environment, University of Nottingham, University Park, Nottingham, NG7 2RD, UK, Accepted 27 August 1999.

[24] *Design and Optimization of the Flywheel Compressor Based on SolidWorks and Fluent*, Ruju Li 1, a, Qiang Gao 1,b and Baocheng Zhang1,c 1 School of Mechanical and Power Engineering of North University of China in Taiyuan, China; aliruju_123@163.com, bgaoqiang919@126.com, cnctzbc@nuc.edu.cn, Advanced Materials Research, *Vols. 915-916 (2014)*, pp 218-222 Online: 2014-04-09, © (2014) Trans Tech Publications, Switzerland doi:10.4028/www.scientific.net/AMR.915-916.218.

[25] *Design and Analysis of Flywheel by Using Finite Element Analysis*, Madhusudhan Reddy K Research Scholar, Department of Mechanical Engineering, Visvodaya Institute of Technology and Science, Kavali, SPSR Nellore(Dt), A.P, India. Suneel Kumar B, Assistant Professor, Department of Mechanical Engineering, Visvodaya Institute of Technology and Science, Kavali, SPSR Nellore(Dt),A.P, India. International Journal of Emerging Technologies in Engineering Research (IJETER), *Volume 3, Issue 2*, November (2015) www.ijeter.everscience.org.