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Modelling & Simulation of Steel Melting plant & Study of Harmonics Generated in Melting Plant for various operating conditions

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***Abstract*—In this paper, by using the data of steel melting plant which contains major non-linear load i.e., induction furnace, we modeled such a system, which contains three 12-tons induction furnace in PSCAD software and simulated for three different operating conditions & studied harmonic pattern.**

Keywords—Induction Melting Furnace;Steel Melting Shop;Harmonics Analysis;Power Quality.

I. Introduction

Here, we use pant details of Shah Sponge & Power Ltd., Tata Nagar. Analysis of results depicts presence of considerable amount of harmonic distortion and its presence is obvious given the fact that major load in plant is non-linear (induction furnace). There are three induction furnaces in the plant which has capacity of 12-tons each and operated at 500Hz frequency. Here, these three furnaces are fading by24-pulse diode converter which is gives supply to the single phase inverter which generates ac supply at 500Hz frequency which is given to the induction furnace load individually. The main issue is, this system produces very high numbers of harmonics from 5^{th} to 25^{th}. And harmonic currents in an electrical power system are a result of non-linear electric loads.

In general, harmonic sources are: Converters, Devices which includes semi-conductor elements, Generators, Motors, Transformers, Lightening equipment working by gas discharge principle, Photovoltaic systems, Computers, Electronic ballasts, Uninterruptable power supplies, Switching power supplies, Welding machines, Control circuits, Frequency converters, Static VAR compensators, Arc furnaces, HVDC transmission systems, Electrical Communication systems.

Harmonic frequencies in the power grid are a frequent cause of power quality problems. Harmonics in power systems cause core and copper loss. This will lead to in increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors. Increase electromagnetic interference with communication circuits.

II. System Description

A. Power support for the plant

Entire load demand of SSPL plant is catered through one steam turbine generator of 15MW, 0.8 p.f. rating; generating power at 11kV. Grid Power received at 33kV through overhead line is used only for the purpose of black start of generator. From Generator Incomer 11kV bus, power is distributed to SMS plant through 33kV/11kV, 15/20MVA, YNd11 transformer. Overall plant distribution is done at 11kV, 33kV and 0.415kV. There are three induction furnaces in the plant which has capacity of 12-tons each and operated at 500Hz frequency. These furnaces fed by 24 pulse converters.

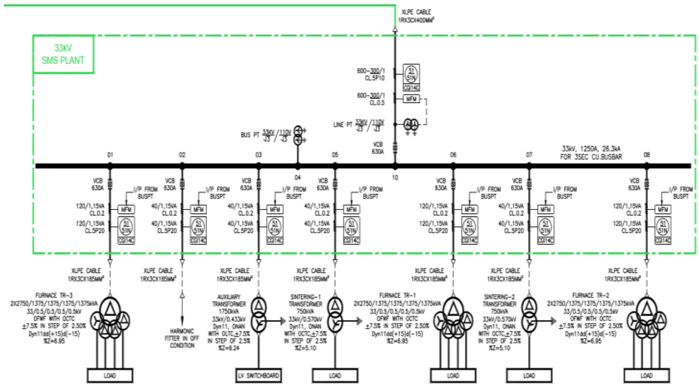

Fig. 1. 33KV SMS Plant

III. Designing of imf

Here, Details of the wiring connection of the SMS Plant is shown in Fig.1. There are three induction furnaces in the plant which has capacity of 12-tons each and operated at 500Hz frequency. Here, these three furnaces are fading by 24-pulse diode converter which gives supply to the single phase inverter which generates ac supply at 500Hz frequency which is given to the induction furnace load individually.

A. Design of IMF Based on Field Measurement[5]

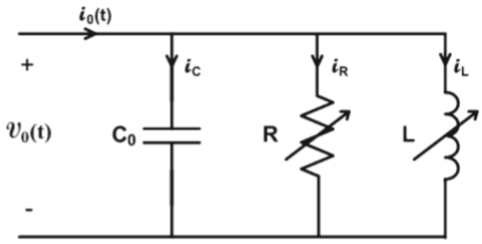

Fig. 2.IMF representation

- IMF can be represented by the equivalent circuit in Fig. 2, where C_O is the capacitance of the resonant capacitor bank in Fig. 2 and R and L are the time-varying operating resistance and inductance of the work-coil–workpiece combination during a melting period, respectively.
- The skin depth δ is a function of resonant frequency f_O of the work coil and electrical resistivity ρ and magnetic permeability μ of various scrap materials, as given in

  $\delta=\sqrt{(\varrho/\pi f_O \mu)}$ where, $\mu = \mu_O \mu_r$, with μ_r as the relative permeability and μ_O as the permeability of free space.
- During melting period, f_O varies to maintain maximum power transfer. As the temperature changes, skin depth also change.
- Operational inductance L is $N^2 P_{eqv}$, where N is the number of series turns of work coil and P_{eqv} is the equivalent permeance of the overall magnetic circuit. Peqv is directly proportional μ_{eqv} equivalent magnetic permeability of the magnetic circuit.
- For ferrous metal scraps, μ_r is varying in a wide range, e.g., from 10 to 5000 for temperatures below the Curie point (770 $^\circ$C), and can be taken as unity above the Curie temperature. Therefore, as the scrap material melts down, considerable reduction in operating inductance L is expected. Since C_O in Fig. 2 is constant, switching frequency f of the inverter should be increased according to below equ. in order to maintain resonance conditions.

  $f = f_O = 1/2\pi\sqrt{(LC_O)}$
- Now, on the other hand, variation in operational resistance R will not be marked as that of l. because it is affected mainly by δ.

- Operational impedance value of R and L of the IMF can calculated from field measurement for various meltingcycles.
- Active power input P_W to IMF at one melting cycle is calculated from

  $Pw=(1/T)\int v(t)*i(t)\ dt$
- Here, R can be calculated by,

  R=(V_W^2)/ *Pw.*

  where V_W is the *true rms* value of the inverter output voltage.
- On the other hand, L can be calculated from

  L= $Vw/2\pi f\, I_{L1}$.

  where V_{W1} is the *rms* value of the fundamental component(at f) of the inverter output voltage and I_{L1} is the *rms* value of fundamental component of the operational inductance current.
- Here, from the field measured value of voltage and current we can easily find out the value of variable R & L at different instant of time and the constant value of the resonant capacitor bank $C_O = 10$uF.

IV. Simulation

Here, simulation of the steel melting plant is done in PSCAD software in which we can easily study the dynamic problems of the power system. Here, in the simulation, source of 11kv is attached with step up(delta-star) transformer. Which step up the supply to 33kv and fed it to the step down(delta-delta-delta-star) transformer. Which step down the supply to 0.5kV. then this 0.5kv supply is given to the 24-puse convertor. Which deliver power to the invertor circuit & this invertor is fed to the IMF.

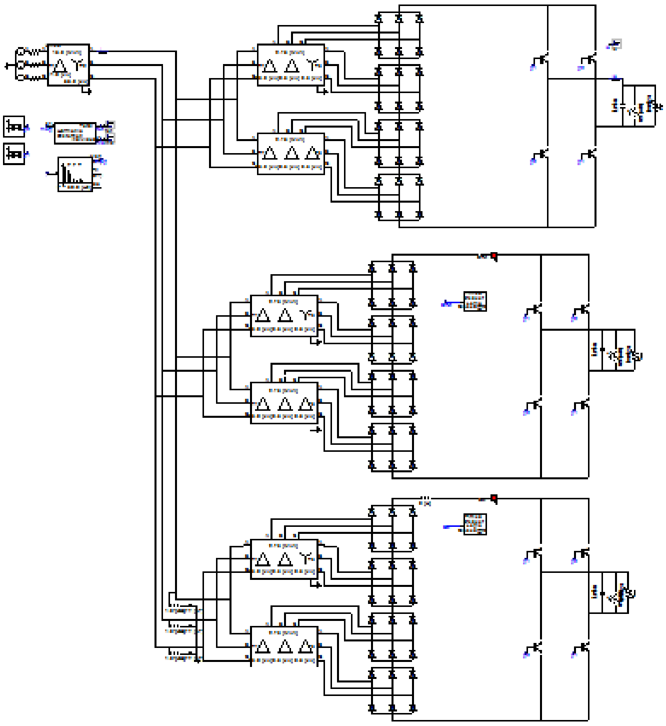

Fig. 3. Total simulation circuit of steel melting plant

Case:1

<u>One Furnace is running and two Furnaces are off</u>, current harmonics are found on generator incomer at average 220.987Amp of running load. And at that time 25th harmonic is dominant one & subsequently 24, 23, 21, 22, 19, 20, 4, 9, 10, 11, 12, 14, 15, 16, 17 harmonics are also dominant.

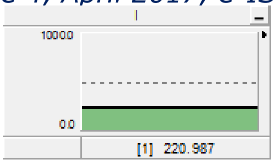

Fig. 4. Average load current for case:1

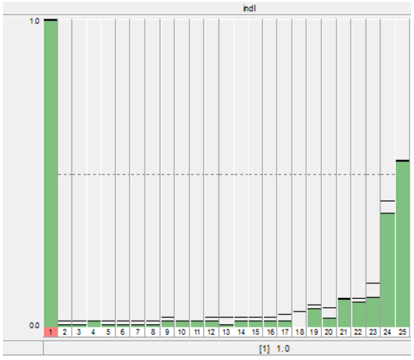

Fig. 5. Current harmonic for case:1

Case:2

Two Furnaces are running and one Furnace is off, current harmonics are found on generator incomer at average 197.899Amp of running load. And at that time 25th harmonic is dominant one & subsequently 21, 23, 24, 7, 5, 9, 11, 13, 15, 17, 19 harmonics are also dominant.

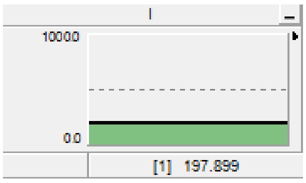

Fig. 6. Average load current for case:2

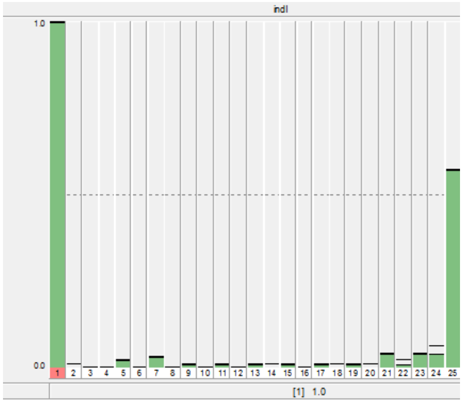

Fig. 7. Current harmonic for case:2

Case:3

Three Furnaces are running, current harmonics are found on generator incomer at average 217.955Amp of running load. And at that time 24th harmonic is dominant one & subsequently 25, 20, 22, 21, 23, 17, 19, 18, 3, 4, 7, 5, 6 harmonics are also dominant.

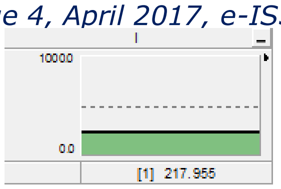

Fig. 8. Average load current for case:3

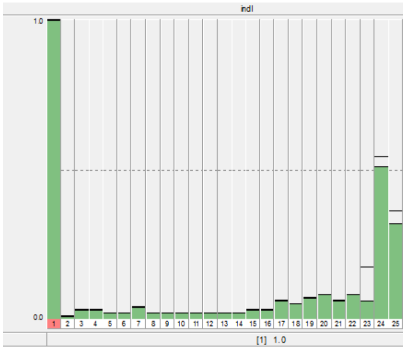

Fig. 9. Current harmonic for case:3

Conclusion

In three different operating conditions, the patterns of generated harmonics are different. So, here we can't use passive filter for reduction of harmonics. Because, the pattern of generated harmonics are not constant so instead of passive filter, we can use active filter for filtering out the generated harmonics.

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