Power Quality Problems in Steel Re–Rolling Industries: A Case Study

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I. Introduction

There are number of steel re-rolling plants running across the India, mostly in small and medium scale category. Steel industries require mainly electrical and fuel energy in efficient and sufficient amount for its proper functioning. Electrical energy is the essential to run the SRRM, but today, it is not capable of running steel industry up to its mark due to power quality issues. The Power Quality (PQ) is the major concern in building the efficient and reliable operation which has direct impact on quality product outcome. One such SRRM unit is audited for the PQ issues and analysed. The impacts of the power quality on peripheral infrastructure are evaluated. This case study also presents the feasible recommendations to mitigate these problems are discussed.

II. Electrical Layout Configuration of Steel Industry

Generalised schematic electrical and mechanical arrangement of any steel industry is shown in Fig.1. Rolling mill gets supplied from utility’s distribution transformer connected at PCC. Rolling motor is coupled to a number of roller sets via flywheel connected on the motor shaft. A flywheel is used to avoid immediate fluctuations in speed of rollers while loading and unloading the process material on rollers, and as an effect to avoid voltage fluctuations on electrical side of motor. The material flow in a typical SRRM unit is also shown in Fig.1 for better understanding of whole process.

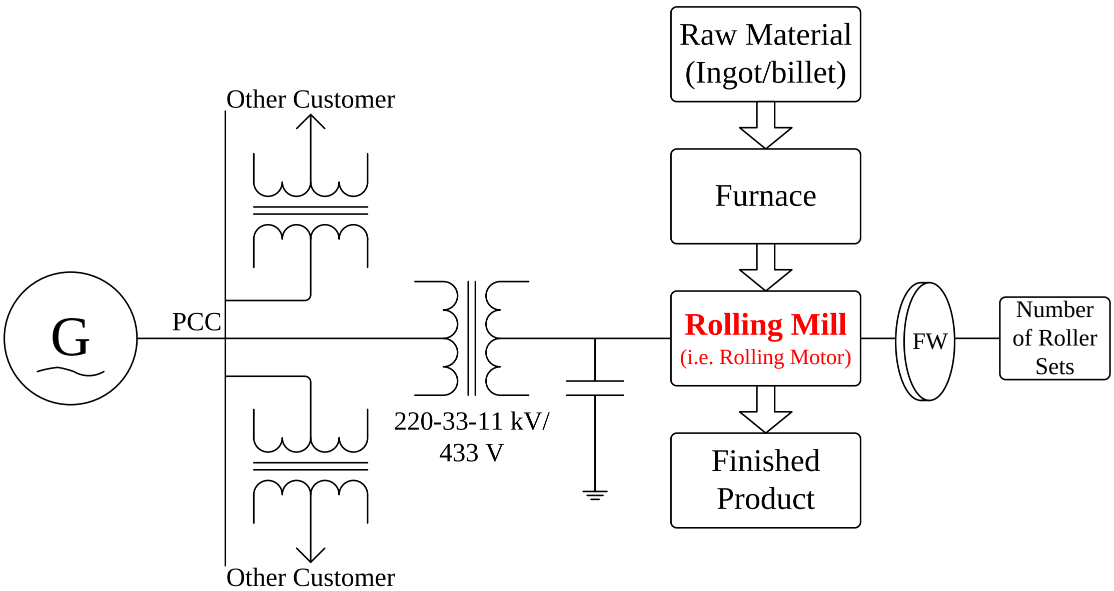

Fig.1 Generalised schematic electromechanical arrangement diagram for SRRMs

The raw materials used in SRRMs are Ingots and Billets which are manufactured from scrap and sponge iron. The Raw Material (Ingots/ Billets) is heated in the Re-Heating Furnace; after a certain temperature is attained they are passed to special rolls to attain the desired size and thickness. Actually, special rolls are the three stages during the production process itself. These three stages are Roughing Mill, Intermediate Mill & Finishing Mill. The heated ingots/billets are passed through the three stands of rolling mill with continuous cooling at rolling stands by spraying with high pressure water. This makes the outer surface of the bars cold and the internal core remains hot. This gives the Bars corrosion resistance characteristics compared to traditional Cold Twisted Deformed (CTD) Bars. The bar is quenched in high pressure water jacket/spray system as it emerges from the finishing stand of the rolling mill. After that, material is passed to cooling bed; from there it goes to end cutting section for cutting into desired (as per requirement) length and finally goes to dispatch section for dispatching.

Fig.2 demonstrates the layout of electrical distribution network of a steel plant. Roughing mill and intermediate mill both are using AC induction motor whereas finishing mill is using DC drives. All three mills are connected to a single transformer which is drawback for this industry and it is discussed in next section. PQ data is only obtained for roughing mill motor at point 'A' marked in Fig.2, by using Megger make PA9 PLUS V604 Portable Power Quality Analyzer. Hence, in this article, PQ analysis and observations are only presented for roughing mill of a steel plant; however, influences of operations of intermediate and finishing mills on roughing mill process are elaborated with PQ data analysis.

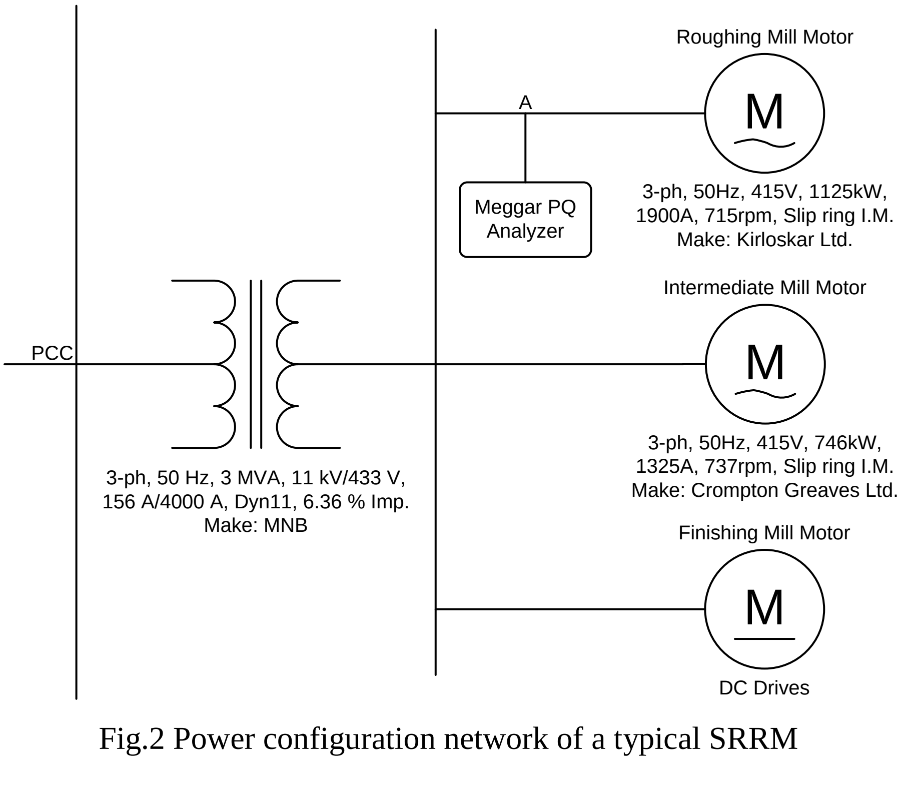

Fig.2 Power configuration network of a typical SRRM

III. Power Quality Data Analysis and Observations

Secondary side line voltage RMS value of utility transformer is 433 V from Fig.1 and Fig.2, whereas roughing and intermediate mill motors have voltage rating of 415 V from Fig.2. This voltage difference only creates the main PQ problem for SRRMs. Hence, it causes the induction motor to go under the saturation mode of operation due to continuous overvoltage. Therefore, motor draws the harmonic components from supply system. Motor has two saturation states, namely high and low states during no–loading and loading conditions respectively. Fig.3 is the outcome of induction motor saturation, where supply phase voltage is purely sinusoidal and mill motor current is distorted. This waveform is captured during the no–load condition of roughing mill. It is obvious that supply voltage remains high while no–pass period and makes the motor to operate in saturated region of B–H curve of core material used.

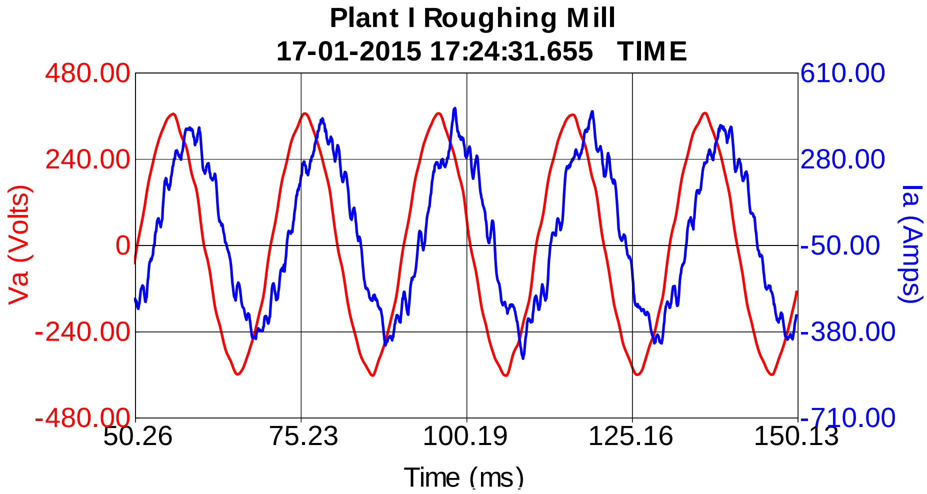

Fig.3 Phase–a voltage and current waveforms captured during field measurement

During steel re–rolling process, rolling motor current changes suddenly and in effect changes the voltage magnitude across the supply line. This continues voltage and current variations can be observed from Fig.4. An instant when heated material comes to a rolling motor to an instant when it completes its number of rolling passes, to become as a finished product, is known as the one process cycle of any SRRM and it is indicated in Fig.4.

Impact of finishing mill on utility supply is the generation of distorted voltage, at common bus bar of transformer’s secondary side, as an effect of rectifier operation. This effect is clearly illustrated in Fig.4 and Fig.6. A rectifier is required for conversion of AC supply to DC supply to feed DC drives (used as finishing mill as shown in Fig.2). Voltage and current both are distorted in Fig.4 (a). Current is distorted due to motor saturation during unloading state. Voltage is distorted by the rectifier operation used for driving the DC motors. It has been proved by Fig.4 (b) where voltage distortion remained same as in Fig.4 (a), but distortion in current has been reduced according to the loading of motor (due to drop in voltage while loading). Hence, it denotes that at that moment DC drive was in working condition with full load.

While transition from unloading to full loading state, with increase in motor load current, supply voltage decreases from its previous value to some amount. This load transition causes voltage fluctuations to appear into utility supply and produces voltage sag and swell. Not only load transitions on roughing mill but also on intermediate and finishing mills trigger out voltage variations in power supply. These voltage variations can be easily observed from Fig.4 (a) and (b). In this way, motor saturation (harmonics), voltage sag and swell are the main PQ problems faced by SRRMs.

Refer to Fig.5 where voltage and current both waveforms are very less distorted i.e. close to sinusoidal nature. Current distortion is minimal because of low saturation effect and overvoltage effect during loading condition and it increases as move towards an unloading state i.e. the end of waveform (apparent from figure). And less voltage distortion doesn’t mean that DC drive is not in operation; actually it is in operation, but with no–load and same reason is applicable for sinusoidal voltage presented in Fig.3.

Changeover from no–pass period to total–pass period is represented in single waveform in Fig.6 where voltage is more distorted in proportion with current; it implies that rectifier used for DC drive is in operation with full loading on DC motor. Distortion in current waveform got reduced after 3-4 cycles of unloading condition, but voltage distortion has remained same.

Phase–a voltage variation is between 239.7 V to 249.7 V whereas roughing mill motor phase–a current is varying from 254 A to 3429 A over the total PQ data recording time period. 10 V voltage drop is very high and abrupt that can damage all types of electronic devices, driver cards, etc. This rapid change in voltage is owing to sudden change in current demand of motor as an impression of loading on roller sets. Voltage THD variation from minimum to maximum is 2.35 % to 16.74 % respectively. This much high voltage THD of 16.74 % is only due to finishing mill drive, else it can’t be possible for any other device already available/installed in an SRRM to rise voltage THD to this much extent. In comparison with voltage THD, current THD variation is very low i.e. 1.11 % to 23.47 %. Harmonic distortion in a current is a consequence of non–linear magnetizing characteristics of induction motor.

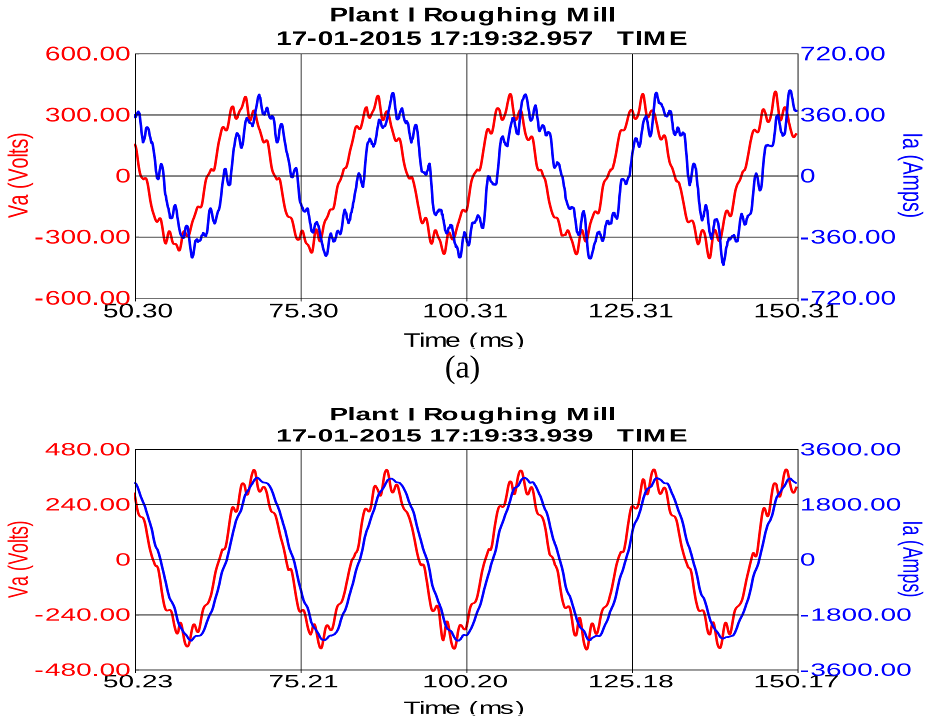

Fig.4 Voltage and current waveforms while (a) no–pass to (b) pass period

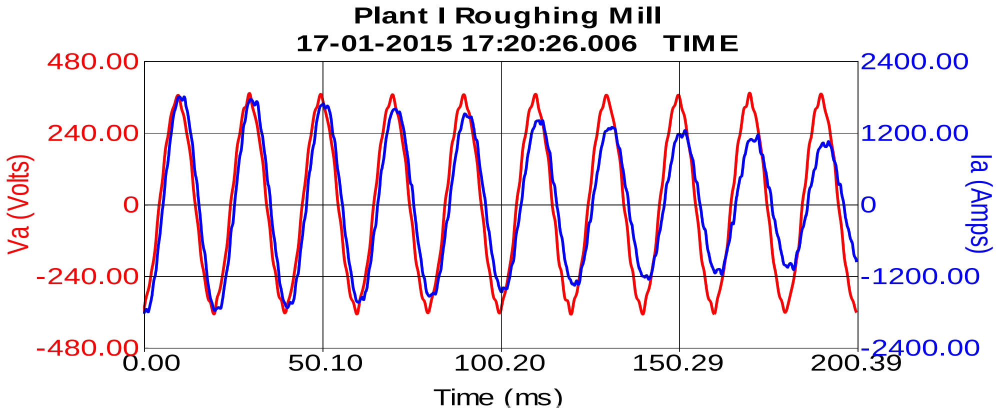

Fig.5 Waveforms of voltage and current of phase–a for showing nearly sinusoidal nature

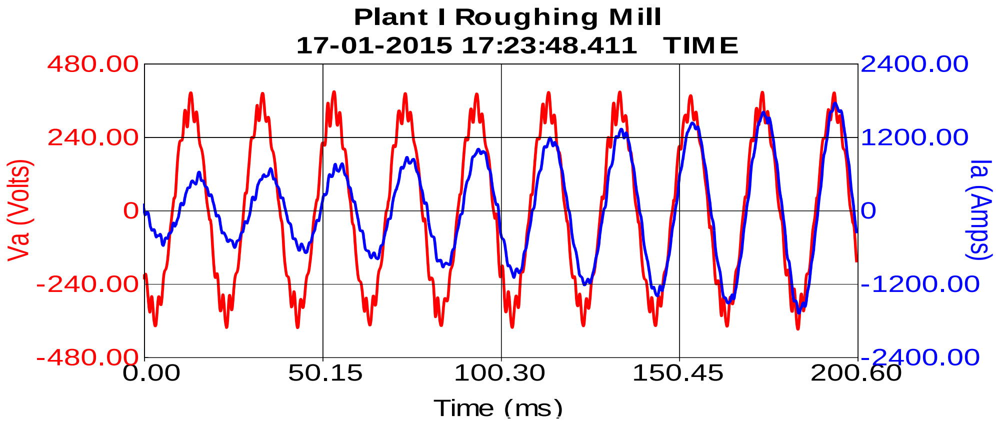

Fig.6 Waveform captured during PQ data recording period while an ingot passing through rollers coupled to a rolling motor via flywheel

IV. Impacts of PQ Problems on Peripheral Devices

Though flywheel coupled on roughing mill motor shaft, PQ impediments are emerging out as major issues for SRRMs and other neighbouring industries. It signifies that connected flywheel is not totally capable of fulfilling its task for which it is employed. This section is dedicated for discussing the effects of PQ deterioration on peripheral devices installed in steel re–rolling industries.

To handle the harmonics, transformer is derated by using K factor. Higher the THD, higher the value of K factor for transformer derating and thus, large percentage of total KVA of transformer is not used in active power supply, else used in reactive power supply.

Voltage drop in a transformer and cable increases with increase in RMS value of current which flowing through them. If RMS current is increased by an introduction of harmonic components, then voltage drop increases by much large amount because harmonic impedances are always greater than fundamental impedances. In addition to above discussed fact, if cable used is of aluminium material, then also voltage drop increases and it is 50 % more as compared to copper cable due to its inherent material property. Skin effect is a well–known phenomenon and becomes more pronounced as frequency is increased. Frequency increases as number of harmonic components after fundamental come into picture and thereby, increases the resistance of a cable and in effect voltage drop. Due to all these voltage drops, line voltage appearing across the rolling motor/s reduces to a considerable amount.

Impact of harmonics on capacitor banks is also a crucial damage to steel industries. A capacitor bank works as a harmonic filter and draws the harmonic currents because of distorted voltage. At certain frequency, resonance condition can occur and permanently damage the capacitor bank. True power factor (TPF) is never equal to fundamental power factor (FPF) in the presence of harmonics. When they are nearly same (TPF≈FPF), the impact of the harmonics are minimal and for (TPF<< FPF), the harmonics are severely influencing the power supply system.

Harmonics increase the number of active power losses in power system such as copper loss (I^2R loss), eddy current loss, etc. and therefore, there is an origination of one more problem i.e. heat dissipation. Lifespan of a cable, transformer and motor windings get declined due to continual handling of harmonics. Zero sequence harmonic components go through the neutral conductor and increase the burden, losses and in turns, heating of a cable.

Parameter	**Recommended Practice**
More than one transformer operating individually.	Operate in parallel to avoid voltage sag and voltage variations.
Using the Flywheel of less capability than required.	Use the flywheel of required capacity.
Running AC & DC drives on same transformer.	Connect AC & DC drives on separate transformers.
Improper or poor Earthing practices.	Grid for all earth pits below ground.
Lighting load	Should have separate lighting transformer detuned.
Neutral Cable	Full/double to avoid heating of neutral conductor due to zero sequence harmonics.

V. CONCLUSION

Numbers of electrical power quality problems have been discussed briefly in this article. A process cycle of an SRRM is also presented. Impacts of both AC and DC drives on the utility supply have been demonstrated. The ill effects of power quality deterioration on peripheral devices and electrical parameters are discussed. Voltage and current harmonic distortions of steel plants are not within the range according to the IEEE standard 519-1992 for Harmonic Control in Electrical Power Systems. Hence, it needs to be taken care with the appropriate technical solutions.