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Adaptable SVC Design Methodology for Power Quality Improvements in Steel Melting Shops

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Abstract*: *In 2019, India was the second-largest steel producer with total crude steel production of 112.3 metric ton [12]. There were lots of development actions taken in the starting of 90's to promote more investments on producing steel and making it a bigger industry supporting country's economy. Even though large amount of produced steel is utilized within the country for infrastructure, automobile and other consumable industries, still India is the seventh-largest exporter of steel. Also, Steel industries are not new to India. The oldest was TISCO and it started its production in 1907. Being said that, we have come long way in technology and science that all the steel plants need to be modernized and adapted to become more efficient, economical and productive. This paper presents one of such technology that being developed in the modern engineering word to make it adaptable in the steel industries where – Efficiency, energy consumption, quality and production can be improved significantly.

Keywords: steel melting shop, SVC, Harmonics, Passive filters.

I. INTRODUCTION

India was the second-largest steel producer In 2019, with total crude steel production of 112.3 metrics. There were lots of development actions taken in the stating of '90s to promote more investments in producing steel and making it a bigger industry supporting Indian economy. In 1991 and 1992 licensing and controlling of steel industries were removed making more and more private industries involving steel production and flow of investments. Even though a large amount of produced steel is utilized in within the country for infrastructure, automobile and other consumable industries, still is the seventh-largest exporter of steel. Also, Steel industries are not new to India. The oldest was TISCO and it started its production in 1907. Being said that, we have come long way in technology and science that all the steel plants need to be modernized and adapted to these technologies to become more efficient, economical and productive. There are a lot of justifications that can be given why power quality is so important in steel production. In steel industries. Large amount of energy for steel production comes from electricity as it can be effortlessly controlled and utilized. Large amount of equipment and machinery are driven by electricity, maintaining good power quality improve: Efficiency; Complete utilization of equipment; Uninterrupted operations of devices. Equipment like rolling mill and strip mills need the smooth mechanical output to produce quality products. Smoot running of these devices is possible only by supplying them with good quality power. Steel melting shops (SMS) involving blast furnace and electric arc furnace require study and quality power for meting steel and to manufacture good quality steel as this is the most crucial part of steel manufacturing. As stated earlier, Steel melting is the most crucial step in steel manufacturing. If you see at large, most of the operations in steel plants are to run Steel melting shop and they are so critical for any steel plant operation.

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A. The large problems associated with bad power quality in SMS are:

Difficult in maintaining Temperature: Temperature determines the quality of steel and the certain process requires to maintain the right temperature for further process. Bad power quality has major impacts on maintaining this temperature. So bad PQ will be challenging for steel producers. Uneven arcing: The even melting of a batch of steel can be best achieved when we have even arcing between electrodes. This process is difficult to achieve during bad PQ power supply. Equipment aging and failure: Bad PQ causes more stress on equipment making them vulnerable for failure and aging. Equipment downtime not only causes production loss, something it even causes critical health hazard for person working in the vicinity. Hazard work environment: PQ issues causes a number of impacts on radio inference and flickers making the vicinity hazard for safe working.

II. POWER QUALITY MEASURMENT

Advancement in electronic and sensors technologies are enabling the engineers to perform PQ (power quality) measurement easily and economical. These measurements can help engineers to analyse and understand the nature of power in a system. Understanding the power quality issues will help to improve the distribution system reliability and to detect potential problems in system.

The application of microprocessor and modern sensors has intensely reduced the price and increased the ability of power quality meters to a higher extent. This increase in processing power has made to add extra features to meters such as measuring long tern transients. Electronic meters have now essentially become information platforms with communications, a local display, and a data acquisition system.

Circutor AR-6 is one of such meters and this meter is used in power quality measurements.

As discussed in earlier, EAF uses an arc to create heat to melt the metal which is nonlinear in nature when you see in terms of electrical behavior those becoming a great source of harmonics. The harmonics in the EAF are non-characterized as the process of meting steel depends on a lot of parameters such are, Operation; materials being melted; a chemical process; the purpose of melting. So generalizing the harmonic source of arc furnace is void if you are understanding the PQ at the supply system. So, Measurement is very important in understanding the signature of individual EAF under study.

Typical, Measurements have to be taken at the source side where the harmonics are generated. In our case, we need to go to an Electrode where there are supplied by heavy water-cooled copper bars. But that is too dangerous as the measurement needs to be taken during operation or even in most cases it's not possible and not worth the efforts are we can find a better location to take up the measurements.

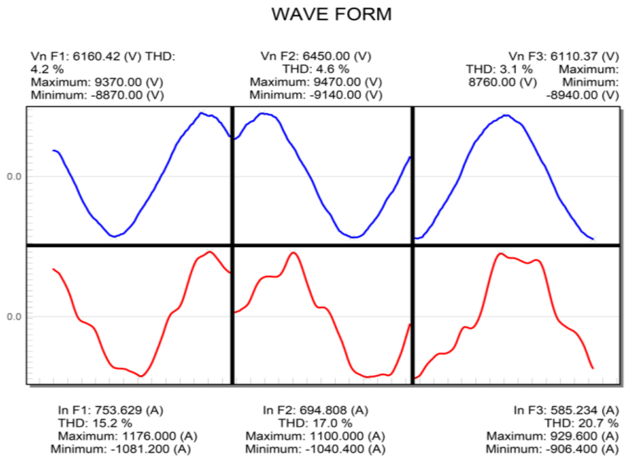

Fig. 1.Voltage and Current waveform captured by measuring instruments during Arc furnace operation.

III. DESIGN METHODOLOGY

Even though there are many international standards with talks about power quality improvements, there is no specific standard that talks about SVC design in detail, that to for an industrial operation. So, at present design engineers depend on multiple standard and previous experience to design modern SVC for power quality improvements in steel industries. This project outcome could be one of such standard or reference document for future design.

For the design of SVC, we can take the help of different part of standards such as IEEE 519 [1], IEEE 1531 [3], IEEE 1031 [4] and many more references listed in the reference section of this article. In our case study, we are designing SVC to compensate one arc furnace, one ladle furnace and to provide reactive power support during under voltage in grid. Considering all this, we have arrived at the size of 30MVAr.

A. Design of Thyristor controlled reactor

Thyristor controlled reactor (TCR) are sized based on the reactive power control range required. In industries, most of the cases, reactive consumption by SVC is not advised to maintain the grid contract power factor as most loads in industries consume reactive power. So, the reactor size should be such the SVC has an operating range from capacitive reactive power to zero. Considering that, TCR size should be equal to the sum of all filter banks.

Within the SVC, harmonic currents are generated by the TCR. The firing angle α is measured from the instant when the thyristor becomes forward-biased. The α angle can be varied between 90 deg and 180 deg. The relationship between the firing angle α and the conduction angle σ is:

$$\alpha + \sigma/2 = \pi. \qquad (1)$$

For α=90 degrees, the thyristor valve is in full conduction while the current is a full sinusoidal waveform. For α=180 degrees, the valve is not conducting. For any firing angle between these two values, the current consists of positive and negative pulses of equal magnitudes.

The rms value of the hatch harmonic component of the TCR current is given by the following formula:

The maximum amplitude of each individual harmonic component can happen at different conduction angles. Based on the above formulae, the harmonic current generated by TCR for LHF and Rolling mill are given in below section.

$$I_h = \frac{4}{\Pi}\frac{V}{X_l}\left[\frac{\sin(h+1)\alpha}{2(h+1)} + \frac{\sin(h-1)\alpha}{2(h-1)} - \cos\alpha\,\frac{\sin h\alpha}{h}\right] \qquad (2)$$

$$\alpha = \Pi - \frac{\sigma}{2} \qquad (3)$$

Were, h = 3, 5, 7, …..
α - Firing angle, and
σ = conduction angle

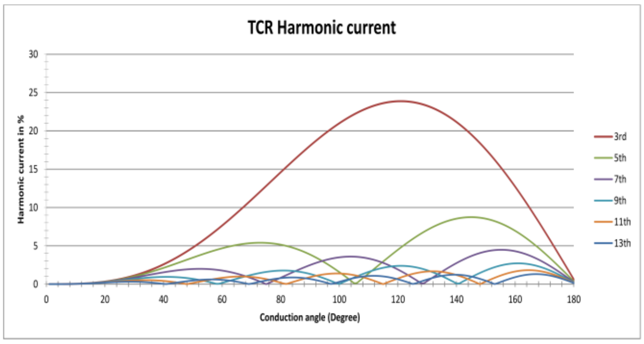

Fig. 2.Current harmonics genrated by the TCR for diferent firing angle.

While designing the individual harmonics filters, we have to cinsider to componsate the harmonics generated by the TCR as well so that it doesn't create more power quality issues.

B. Design of Harmonic filters

Harmonic filter design is one of the important parts of SVC design. Filters not only help us to provide sink for harmonics generated but also provide best source for reactive power. To increase the effectiveness of the harmonic filtering, it is best we divide the MVAr to multiple single tuned filters but not to overcomplications by selecting too many of them. Best way to identify the filters tuned value is to understand the measurements and expected harmonics generation from TCR. From the graph in figure 2, we can see that the harmonic current for 2, 3, 4 and 5 are high and are more responsible for total harmonics distortion.

So it is best that we design for these values. Also, we should make sure the select the filters to best match with its operation and impact.

Considering that, Table 6 list the filters parameters at we have designed. The values are tuned and simulated to check their impact on network.

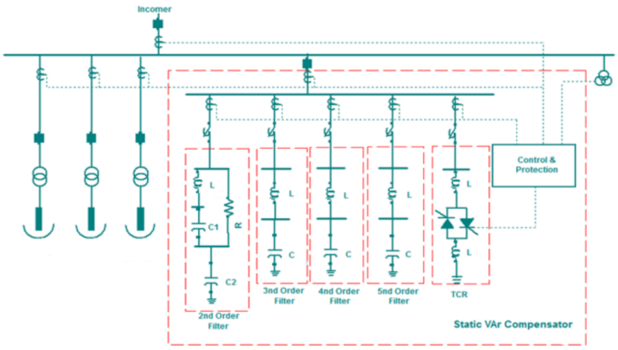

Fig. 3.Proposed SVC schmatics.

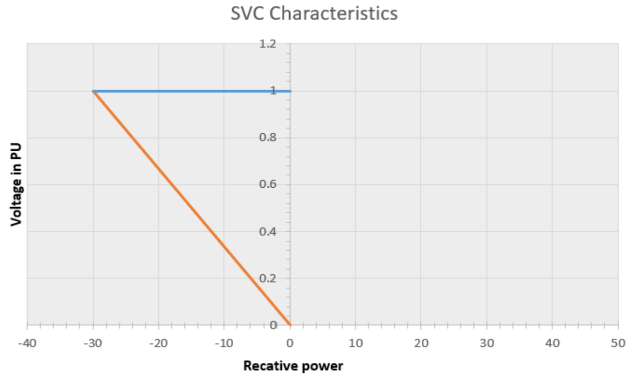

Fig. 4.Desired reactive and voltage response of proposed SVC.

IV. MODELING AND SIMULATION

The sample network provided in IEEE 399 standard is used to create typical industrial network to achieve more relatable results to actual system. Also, it is very important to understand the filter behavior with all the components in network. Cables and other compensating network may have adverse effect tuned value and will do more bad than a good.

Understanding the behavior of filters and varying network parameters is very critical in SVC design. The designed SVC need to make sure the power quality of network as well as the harmonics generated by TCR.

Following points need to be taken care when we are understanding the SVC response with network:

1. SVC behavior with varying grid impedance.
2. SVC behavior with long cable and transmission lines.
3. SVC behavior with other compensation devices.
4. SVC behavior with varying load and generations.

Considering all the above points, simulation is been carried out to understand and fine tune the SVC parameters.

A. Frequency spectrum with varying grid impedance

SVC interaction with the grid is more important as its impedance and reactive power response depend on it. Modeling grid as a source behind and impedance would work considering inductive impedance being major components. Since the SVC circuit is in parallel with the grid impedance, a high fault grid could over dominate the frequency response at the SMS bus and the visa versa.

The below figure presents the impedance spectrum at SMS bus with varying grid fault currents.

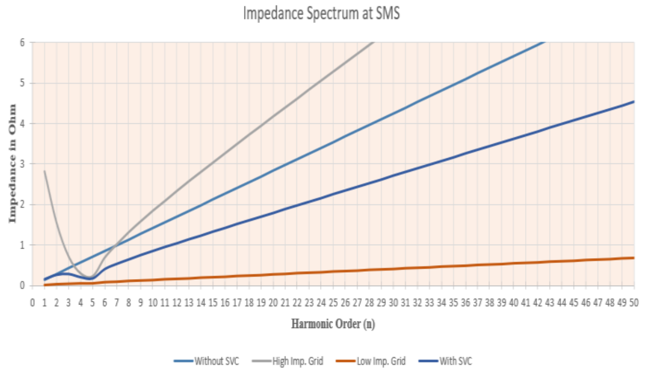

Fig. 5. Impedance spectrum at SMS with varying grid impedance.

B. Frequency spectrum with varying Cable and transmission line length

In most distribution networks, cable capacitance adds more impact in tuned values. If the designer plan on feeding the SVC circuit with cables, then he has to carefully select the appropriate length of cable required.

In most circuit, system impedance which major part as inductive in nature parallel resonate with cable shunt capacitance at higher frequency (above 25th order). But, when the filter circuits are implemented, the circuit becomes dominated with the capacitive impedance and will have parallel resonance at a lower frequency level.

When long cable lengths come in, the circuit becomes more and more capacitive and will push the parallel resonance to even lower values. If not selected properly, long cables could nullify the effects of filters design and could cause an adverse effect if not understood well.

The below figure shows examples with varying cable lengths.

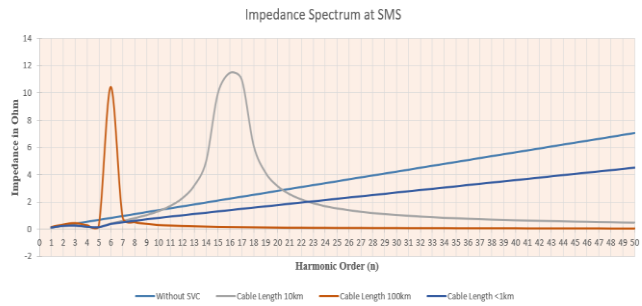

Fig. 6.Impedance spectrum at SMS with varying cable lengths

C. SVC behaviour with varying load and generations

SVC behavior with varying load can be briefly analyzed by running a study state analysis by means of load flow algorithms with considering steady slope for its control response. Detail understanding of control response is further understood if we know exact control blocks used in for thyristor control.

Running transient stability study could provide a clearer picture in it. But in our case, simple study cases with different scenarios will give us the desire study results. The below table shows the SVC response for different scenarios.

Table-I: SVC response with varying systme parameters

Scenario			Bus Voltage at SMS (pu)	
			Without SVC (with Fixed Compensation)	With SVC
Grid	LAF	EAF		
1.0 pu	OFF	OFF	1.12	1.00
1.0 pu	ON	ON	1.00	1.00
0.95 pu	ON	ON	0.95	1.00
1.0 pu	ON	ON	0.87 (Cap off)	-

D. Harmonic spectrum

At the end, most important aspect of the whole exercise is to improve the power quality of the SMS. If all the parameters that are previously discussed are well taken care, then the harmonic spectrum at the SMS could improve as per the design. The below graph shows the voltage harmonic distortion at SMS for with and without proposed SVC.

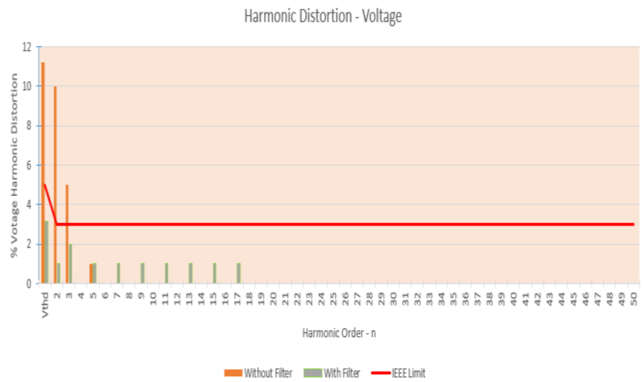

Fig. 7.Voltage harmonic distortion at SMS for with and wothout proposed SVC

V. CONCLUSION

Though SVC was widely used in transmission system for reactive power control, using it in distribution system for reactive power and power quality is developing still as there are lot more challenges to tackle.

This paper gives the more insight on the design method that can be used in one of such distribution systems where detail understanding of its response with system parameters are understood via simulation. The results of such simulation give a clear understanding on possible outcomes and how to overcome them as well to achieve adaptable design methodology.

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