Improve of Power Quality Profile in Steel Industry by Application Static Var Compensator

Boonlert Suechoey and Pairoj Kajoijilertsakul

***Abstract*— Accessing in depth of power quality parameter is turn to popular issue nowadays. Especially, at point of common coupling (PCC) which is the most importance since at this point power flow are bi-directional between utility provider and consumer. Moreover, interconnected load which in consider as non-liner load most likely to be decrease of power quality resulting in limited reserve during unexpected accident occur in power system. As a result of this, further study on these such load is requiring as well as appropriate action must be taken. Electric arc furnace knows as one kind of non-linear load which widely part of steel industrial manufacturing process. Thus, in this paper will focus on electrical system in those area which in install of electric arc furnace equipment. Accessing of electrical parameters will be present as well as an appropriate method to reduce impact of these such application in term of voltage distortion.**

***Keywords*— Electric arc furnace (EAF), Power quality (PQ), PSCAD/EMTDC, V-I Characteristics, Static var compensator (SVC)**

I. INTRODUCTION

Dramatically increasing in load over a decade due to economic growth resulting in awareness of power quality issue. Power quality play as an importance topic which become widely concern in a past few years. Furthermore, power quality also significance associate with spinning reserve of system. Majority concern come from interconnected load from electricity consumer especially, load which classify as non-linear characteristics. Electrical equipment which part of manufacture process in steel industry called electric arc furnace (EAF) is an example of non-linear load. In addition to, steel industry considers as a high percentage of gross domestic product in Thailand. As a result of this, the modelling of electric arc furnace as well as equivalent circuit of interconnected system will be performed through PSCADE/EMTDC program in order to access across power quality issues at point of common coupling (PCC) between manufacture and provincial electricity authority (PEA). After simulation the result reveal that operating of electric arc furnace impact to system voltage profile which the voltage level not meet the minimum requirement of voltage level at point of common coupling. Thus, an appropriate action should be taken into consideration in order to maintain or recovery of power system. Static var compensator (SVC) which know as one equipment of flexible alternating current transmission system (FACTS) is the most popular devices apply to compensate those constrain. As a result of this, static var compensator will be add in term of PSCAD/EMTDC format at each factory. In this paper, comparison of voltage profile during operating of electric arc furnace under denote conditions with cooperating of static var compensator and non-cooperating of static var compensator will be discuss.

II. ELECTRIC ARC FURNACE MODEL

Electric arc furnace modelling based on non-linear characteristics. A non-linear load is quite difficult to determine the characteristics. In this study, electric arc furnace based on three majority parameters of mathematical model as show in (1). Three majority parameters are arc radius, arc voltage and arc current. Those parameters are applying in order form characteristics curve called V-I relation.

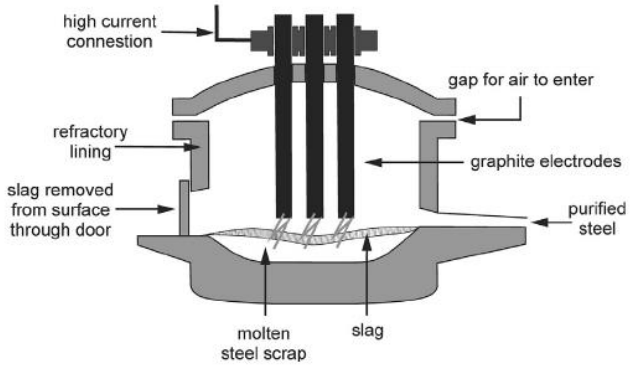

Fig. 1. Modeling of electric arc furnace

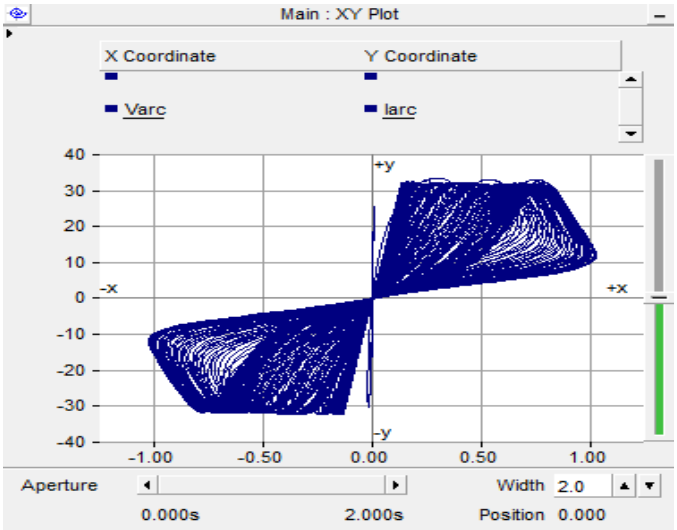

Fig. 2. V-I Characteristics

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$$k_1 \cdot r^n + k_2 r \frac{dr}{dt} = \frac{k_3}{r^{m+2}} \cdot i^2 \qquad (1)$$

The equation as show in (1) represent the behavior of electric arc furnace which denote by three majority parameters k_1, k_2 and k_3 which represent as follow definition

k_1 – Conversion from electric power to heat and transfer to natural
k_2 – Increasing of power due to internal arcing in electric arc furnace
k_3 – Power transfer to energy for arcing

III. STATIC VAR COMPENSATOR

Static var compensator are most commonly integrated with power system in order to increase system stability as well as enhance of reliability. The most powerful feature of static var compensator is to control of reactive power in order to maintain voltage profile of the system leading to increasing of system reliability during transient conditions. The equivalent circuit of static var compensator and the equation which associate to control of input and output reactive can be show in Fig. 2 and (2), respectively.

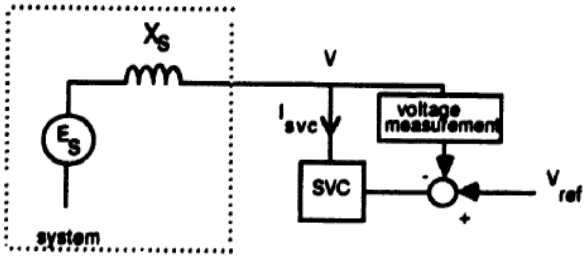
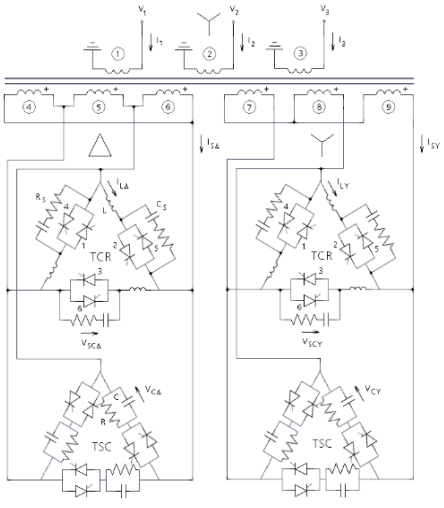


Fig. 3. Modeling of static var compensator



Fig, 4. Equivalent circuit of static var compensator

$$|Q_{SVC}| = U_i^2 \cdot |B_{SVC}(\alpha)| = U_i^2 \cdot \left| \left(B_C + B_L \cdot \left(\frac{2\pi - 2\alpha - \sin 2\alpha}{\pi} \right) \right) \right| \qquad (2)$$

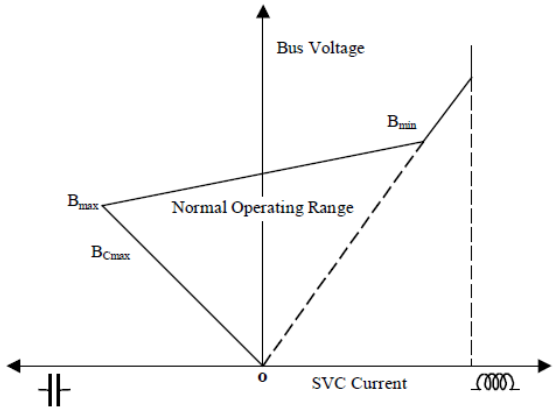


Fig. 5. Equivalent circuit of static var compensator

$$|Q_{SVC}| = U_i^2 |B_{SVC}(\alpha = 90^\circ)| \qquad (3)$$

$$|Q_{SVC}| = U_i^2 |B_{SVC}(\alpha = 180^\circ)| \qquad (4)$$

IV. SIMULATION SCENARIO

In this study, the severe conditions are applying as three electric arc furnaces are operated at the same time. These electric arc furnaces are connected through 6.6 kV voltage level of each individual factory which has connected at point of common coupling at 115 kV system. At each denote point A, B and C as show in Fig. 3 represent voltage profile at point of common coupling between steel industry and utility of TATA, SYS 1 and SYS 2, respectively. Whereas position D presentative as Rayong 2 (RY 2) substation voltage level.

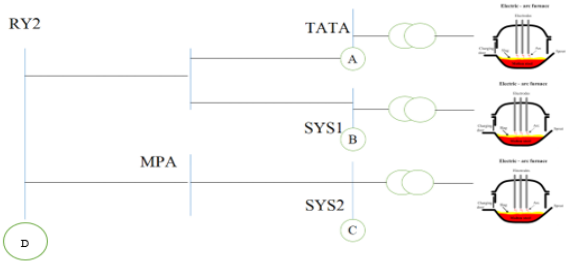


Fig.

6. Equivalent circuit of static var compensator

As initial conditions, the normal voltage are measure as background voltage data. During assign condition that three electric arc furnaces are operated at the same time. The four point of voltage profile are measure to comparison the voltage distortion as show in Table I. Whereas the voltage waveform at each point can be express in Fig. 7,8,9,10 represent voltage at point A, B, C and D, respectively.

TABLE I: COMPARISON VOLTAGE AT EACH SIMULATION

Position	PSCAD /EMTDC (kV)	PSS/E (kV)	Powerworld Simulation
A	115.32	114.39	115.30
B	115.27	115.28	115.30
C	115.45	115.77	114.69
D	115.98	115.89	115.98

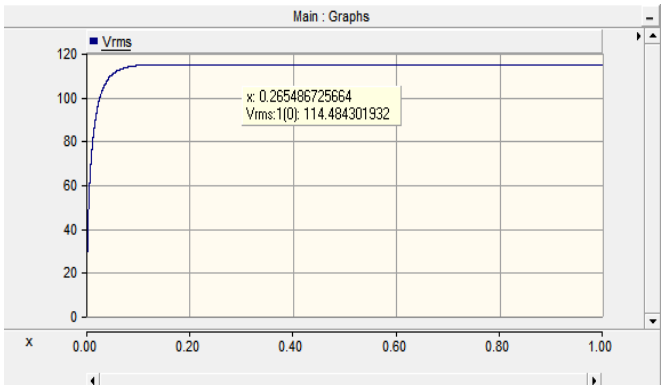


Fig. 7. Voltage profile at position A

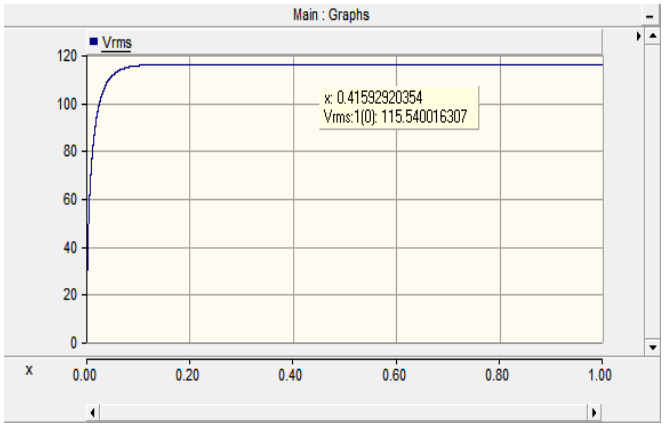


Fig. 8. Voltage profile at position B

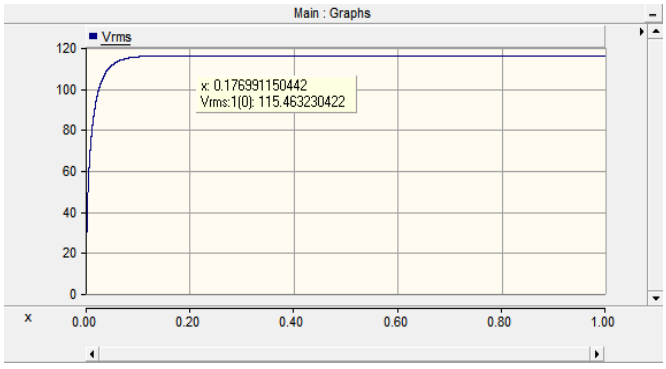


Fig. 9. Voltage profile at position C

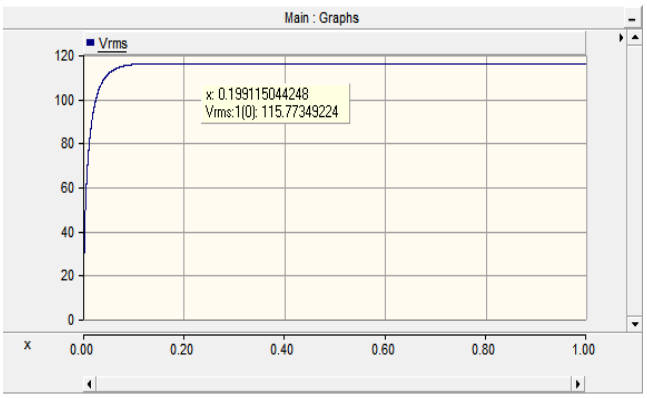


Fig. 10. Voltage profile at position D

Selection of the worst operation of electric arc furnace are perform which in this study denote that three-electric arc furnace at each position operate simultaneous. As a result of this, comparison voltage at each point are show in Table II. The results show that voltage profile significantly decreases.

TABLE II: COMPARISON OF VOLTAGE AT GIVEN CONDITION

Position	PSCAD /EMTDC (kV)	Under given condition (kV)
A	115.32	109.47
B	115.27	110.24
C	115.45	109.29
D	115.98	114.94

Refer to power quality requirement at point of common coupling (PCC) between utility supplier and consumer which issue by Provincial Authority of Thailand (PEA) as show in Table III.

TABLE III: VOLTAGE REQUIREMENT AT PCC

Voltage level (kV)	Normal Conditions (kV)		Emergency Condition (kV)	
	Max	Min	Max	Min
115	120.7	109.2	126.5	103.5

From the voltage profile, it is clearly can be conclude that operating of electric arc furnace are consider as intensive care load since those loads are effects to the voltage level. The voltage profile at each point illustrates that point A, B and C nearly reach the lower limitation of voltage level under normal condition. Hence, these reflect that the system has very limited reserve which might be leading of voltage collapse during unexpected event occurs. Thus, static var compensator are install in order to enhance system security. The study shows that static var compensator has a sufficiency efficiency to compensate voltage profile. The result comparison of voltage profile before and after are display in Table IV.

TABLE IV: COMPARISOR VOLTAGE BEFORE AND AFTER CONNECT SVC

Position	Voltage before connected SVC (kV)	Voltage after connected SVC (kV)
A	115.32	109.47
B	115.27	110.24
C	115.45	109.29
D	115.98	114.94

V. CONCLUSION

From these study, it obviously shows that electric arc furnace considers as load which resulting in power quality issue. Especially, in view of voltage distortion at point of common coupling. According to requirement at point of common coupling which issue by provincial electricity authority. The result discloses that during operating of electric arc furnace the voltage at point of common coupling from three areas might not meet the requirement or has an insufficient reserve. Since reserve in electrical power system is one of the most importance during transient condition in order to withstand deviation from nominal operation point. Further action taken in order to limit the effect of lower voltage profile by integrated of static var compensator. The simulation shows that static var compensator can be apply to improve voltage profile at each point of common coupling. For further work, in depth information in order to analyze smoothness of voltage profile in term of fluctuation index should be perform. These fluctuation index will be measure in term of short term severity which show the deviation of voltage per time. This information is also majority part for further analyze system stability as well as reliability issue.

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