A Case Study of Western Rajasthan Wind Energy Effects In Power System and Remedies

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***Abstract*— Wind generation is currently the leading form of new renewable generation. The power generation through wind energy totally dependent on the flow of the wind due to uncertainty and randomness of wind flow, the generation of power is quite fluctuating in nature and large-scale wind farms may cause significant impact to the stability and power system safety. This paper presents a case study of Western Rajasthan which become high wind power penetration zone. Which includes the requirements of the reactive power mitigating device, the analysis of voltage, active and reactive power flow under condition of sudden increase of wind power and effect of reactive power compensating device Static Var Compensator if it is placed at major GSS of Western Rajasthan. To analyze the situation Mi-Power software is used. It is concluded that for Rajasthan power system the installation of suitable capacity SVC is must, preferably at the main wind bus.**

***Keywords*— wind power, static var compensator, reactive power, wind power variability, renewable energy**

I INTRODUCTION

World where a majority of electricity generation is based on nonrenewable sources, it is clear that the utility planning and global demand growth have the potential to increase penetrations of renewable energy on electricity grids worldwide. This will have profound effects on the grid operation and stability, which will in turn affect the operation of renewable resources such as wind and solar energy as well as the operation of other resources and equipment connected to the grid. Presently wind power generation has exceeded 432 GW and by the end of 2020, the installed capacity is expected to be around 1950 GW. Power electronic converters and controllers make it possible to integrate large wind power generation to the grid [1]. The unpredictable nature of wind power prevents the wind power plants to be controlled in the same way as conventional plants [2]. The wind power generation can mitigate environmental pollution, reduce power losses, reduce on-peak operating costs [3]. The knowledge of actual time varying availability of wind speed is essential for prediction of wind power generation in grid connected wind power plants. The wind power generation having the effect on time as well as distance dimension, Fig.1. [4]

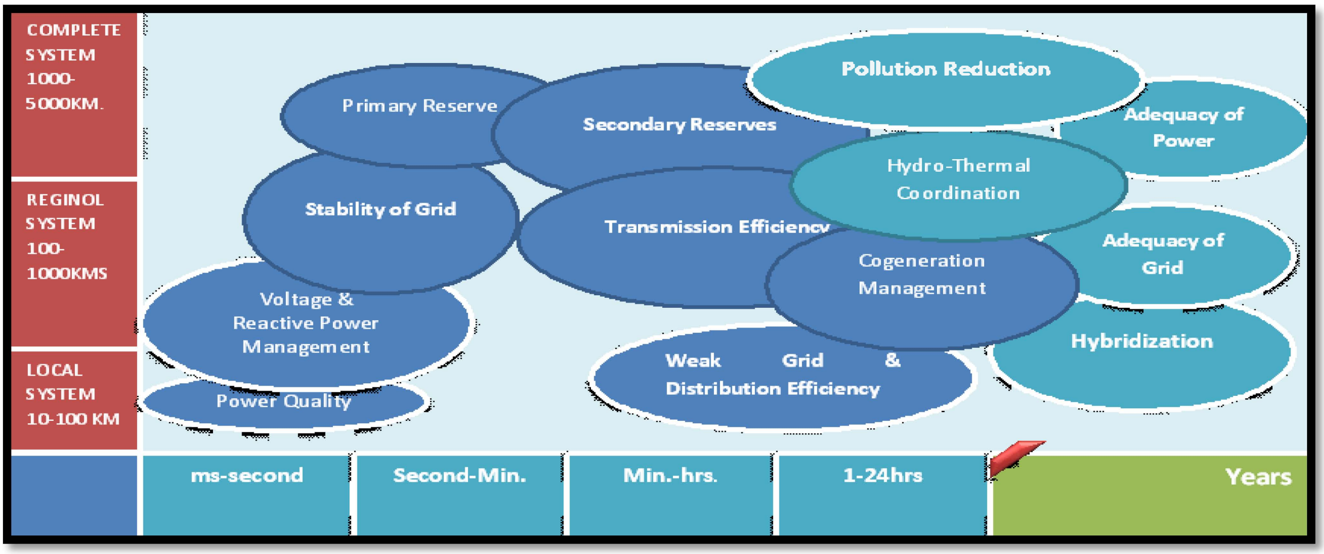

Fig.1 Impact of Wind Power in Power System

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A case study, of high wind power penetration area in Rajasthan is presented in this paper, which also includes the requirements of the reactive power mitigating device, the analysis of voltage, active and reactive power flow under condition of sudden increase of wind power and effect of reactive power compensating device Static Var Compensator. The power system considered is Western Rajasthan (India).

This paper is divided into six sections. Starting with an introduction in Section I, Section II covers wind power variability including Rajasthan power system. Section III details the static var compensator considered for study. The various analyses and simulation performed for case study are covered under Sections IV Result analysis is carried out in in Section V. Finally, the conclusions are drawn in Section VI.

II WIND POWER VARIABILITY

The meteorological and topological factors are major factors which influence on the wind characteristics at any site which affects the dynamic loading of wind turbine [5]. The wind energy are unpredictable in nature and wind power flow change abruptly in twenty four hours and varying day by day. Major concentration of wind power is in the Western sector of Rajasthan. Fig.2 depicts the major wind power installation in different districts of Rajasthan.

Fig.2. Major Wind Power installation in Rajasthan

The wind energy having the short term and long term variability and even consecutive wind power flow pattern are having variance. As such, wind power generation patterns are also different and having very significant variability between them. In Fig. 3 and Fig. 4 shows the wind power generation pattern in two consecutive days in Western Rajasthan Jaisalmer.

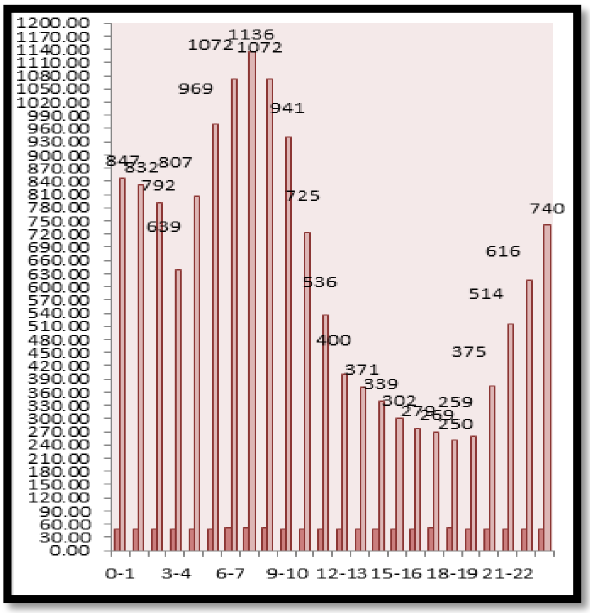

Fig.3. Wind Power Generation Pattern on 31/05/2015

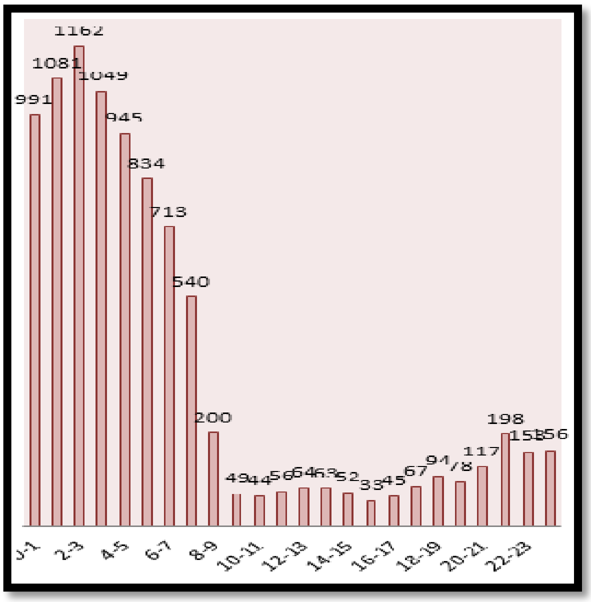

Fig.4. Wind Power Generation as on 01/06/2015

In Western Rajasthan, the major transmission system is comprised of 220kVand 400kV lines connecting Jaisalmer Barmer and Jodhpur evacuates conventional power generation at Giral and Ramgarh and wind power generation at Jaisalmer, Fig.5.

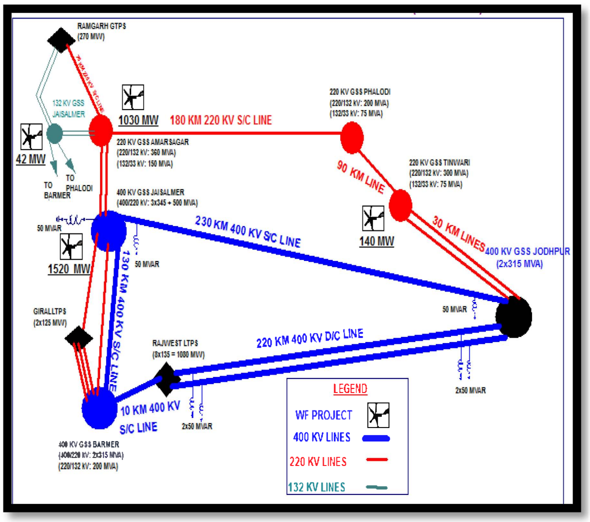

Fig.5. The Power Evacuation network of Western Rajasthan

III STATIC VAR COMPENSATOR

Reactive power control is important because all wind farm technology do no not have the same capability. The wind farm as seen are installed in remote areas; therefore the reactive power has to be transported over long distances resulting in power loss. The wind farm has to provide reactive power control in response to voltage variation. The shunt connected FACT devices such as Static Var Compensator (SVC), which is dynamic reactive power compensator whose reactive power output depends upon the system voltage. SVC is adopted for control of bus voltage magnitude and to bring the system near to unity power factor. The SVC is preferred to used, for improvement in the stabilization of steady-state and dynamic voltage, continuous control of power factor[6]. The reduction in harmonics and phase imbalance also observed with the application of SVC. The voltage at which SVC neither absorbs nor generate the reactive power is called Vref, generally this voltage is adjusted in range of ±10 to ±15%, The slope represents a change in voltage with the current of SVC and considered as slope the reactance X_{SL}, The SVC current is given by:-

$I_{SVC} = JB_{SVC} V$

Where $B_{SVC} = B_{TCR} + B_C$

$B_{SVC} = B_L\{(\pi - 2\alpha - \sin\alpha)\} + B_C$

Where $B_L = 1/X_L$ and $B_C = 1/X_C$

The reactance of SVC can be defined as

$X_{SVC} = X_{TCR} X_C / (X_{TCR} + X_C)$

Where $X_{TCR} = \pi X_L / (\sigma - \sin\sigma)$

Therefore, $X_{SVC} = \pi X_C X_L / \{(X_C(\sigma - \sin\sigma) - \pi X_L\}$ (1)

Where $\sigma = 2(\pi - \alpha)$

$X_{SVC} = \pi X_C X_L / [X_C\{2(\pi - \alpha) + \sin 2\alpha\} - \pi X_L]$

$Q_{SVC} = V^2_{SVC} / X_{SVC}$

$Q_{SVC} = V^2_{SVC} [X_C\{2(\pi - \alpha) + \sin 2\alpha\} - \pi X_L] / \pi X_C X_L$ (2)

If we change α the firing angle, the value of reactance X_L of the reactor changed.The volt-amp characteristics of SVC are given in Fig.6 The SVC characteristic, steady state and dynamic, describe the variation of SVC bus voltage with SVC current r reactive power.

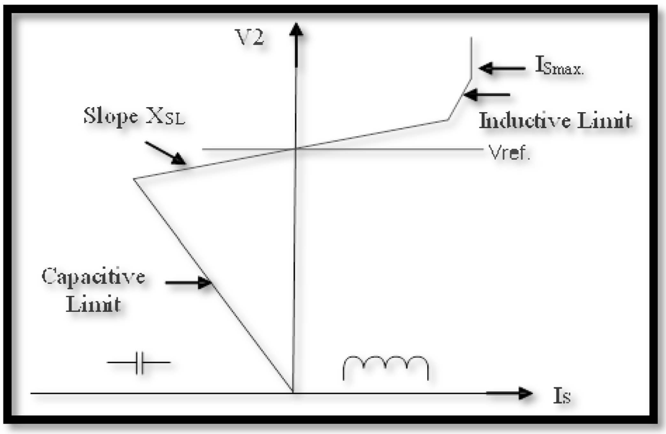

Fig.6. Steady State V-I Characteristic of SVC

Block diagram of SVC comprises of TCR-FC is shown in Fig.7.

IV ANALYSIS AND SIMULATION

For case study the power system network considered is of Western Rajasthan (India) having a high wind penetration area having total connected wind power 2000 MW in three buses, namely Akal 220 kV, 1600MWat Amarsagar (Jaisalmer) 220kV, 300MW & Amarsagar (Jaisalmer) 132 kV, 100MW, with actual field system network comprising of 29 Bus including wind power connected buses, Generating station bus, SVC bus and other power transfer buses 400kV (4), 220 kV (10), 132 kV (9), 33kV (1) and 11kV(5). Total 37 Transmission lines of voltage level 400kV, 220 kV and 132KV level, with shunt reactors connected to both ends of 2 numbers 400kV transmission lines.

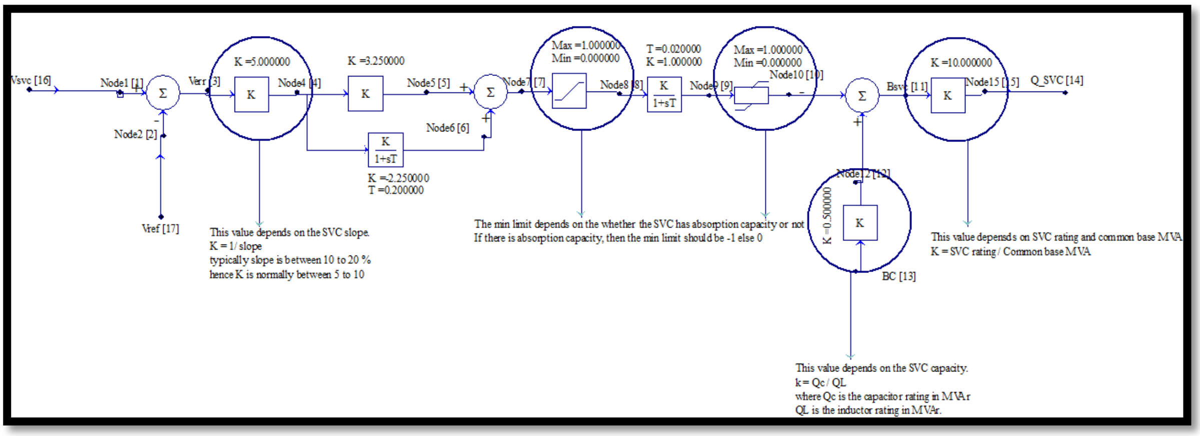

Fig.7. A complete block diagram of SVC with TCR and fixed capacitor for load flow study

Wind power is represented as negative load. The interconnection of 29 bus system, shown in Fig.8, further this system connected and part of 657 bus Rajasthan power system. The Western Rajasthan has 2000MW wind power installation, looking to this system requirement (±) 500MVAr capacity SVC is used for analysis of static and dynamic reactive power need of Western sector.

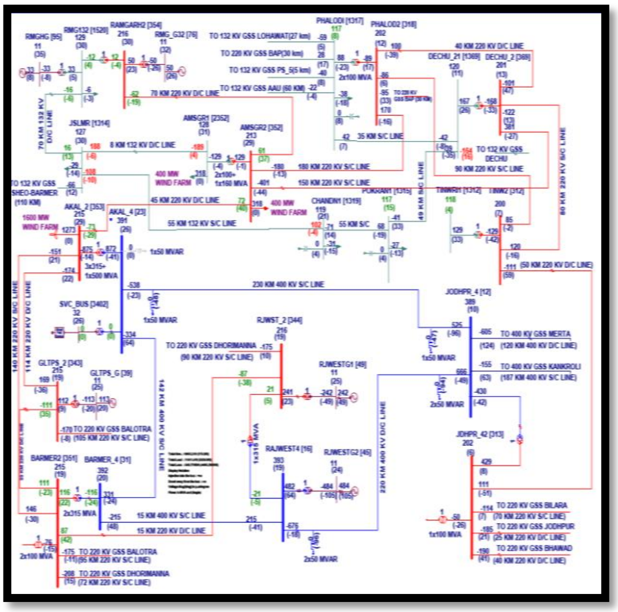

Fig.8 Single Line Bus Diagram of the High Wind Penetration Area in Rajasthan

For the analysis of dynamic reactive power, three conditions are simulated, i.e., the addition of 25% of installed wind generation capacity at wind buses from initial zero MW capacity after 5 seconds, 50% after 10 seconds and 75% after 15 seconds[7-9]. The effect of altering the location of SVC at 400 KV Akal bus as compared to SVC at 400 KV GSS Jodhpur and Barmer, on 400 KV bus voltages, voltage of the wind buses, flow of reactive and active power in 400kV transmission lines, and swing curves of M/s Raj West LTPP and Ramgarh GLTPP are shown in Fig.9- Fig.13.

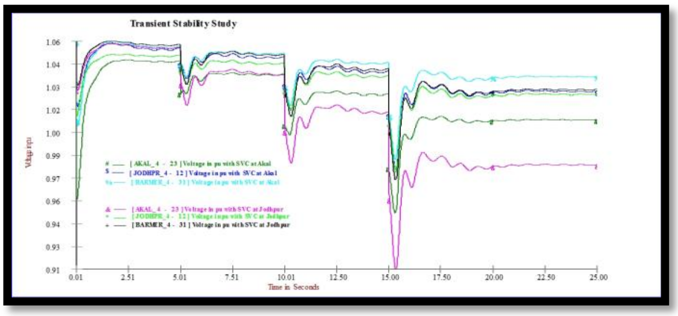

Fig.9 Voltage at 400kV GSS with SVC location change

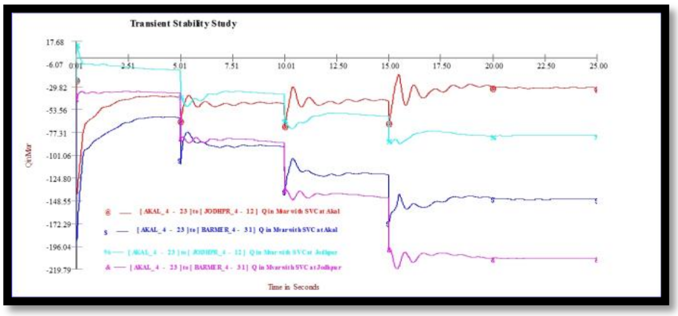

Fig.10 Reactive Power Flow Variation in 400kV Lines with Change of Location of SVC

Fig. 11 Active power flow in 400 kV lines

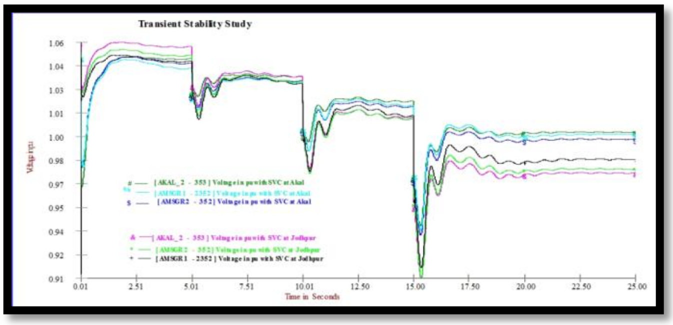

Fig.12. Wind Bus Voltages with SVC at Akal and Jodhpur

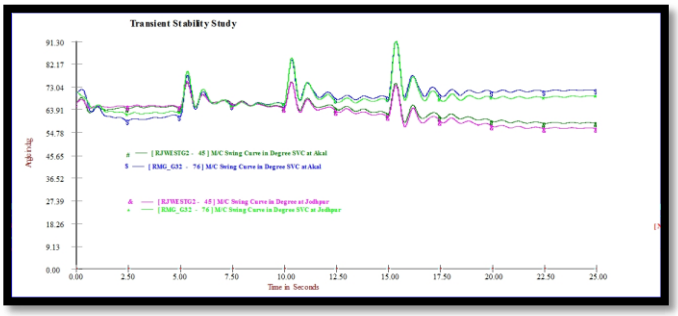

Fig.13Swing Curve of M/s Raj West & Ramgarh PP

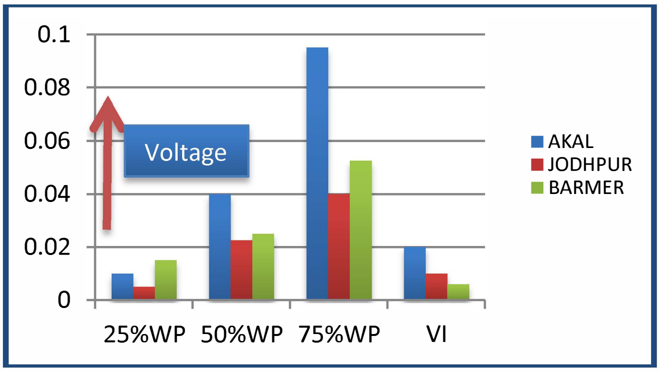

Fig.14 Improvement in voltage dip at 400k V GSS under Transients Condition with SVC at Akal

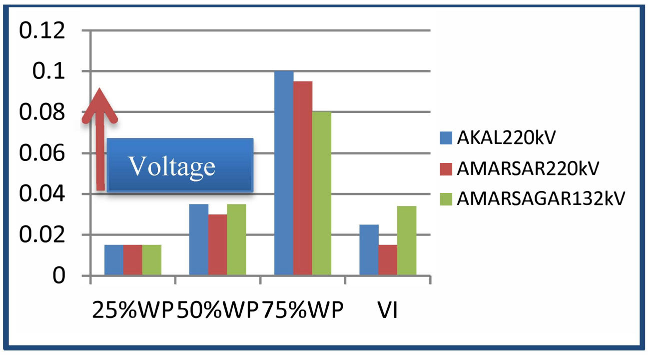

Fig.15 Improvement in Voltage Dip at 220 &132k V GSS under Transients Condition with SVC at Akal

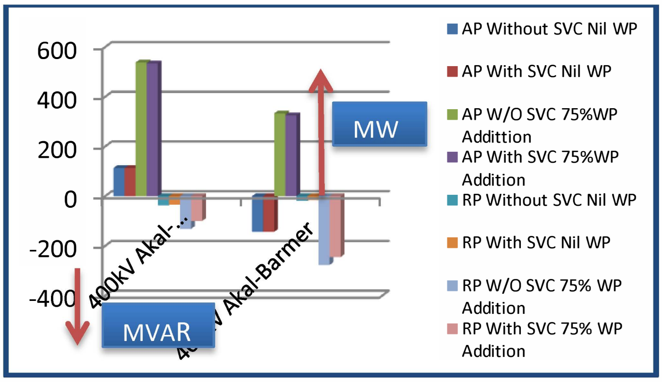

Fig.16 Flow of Active and Reactive Power in 400k V Transmission lines, Without and With SVC

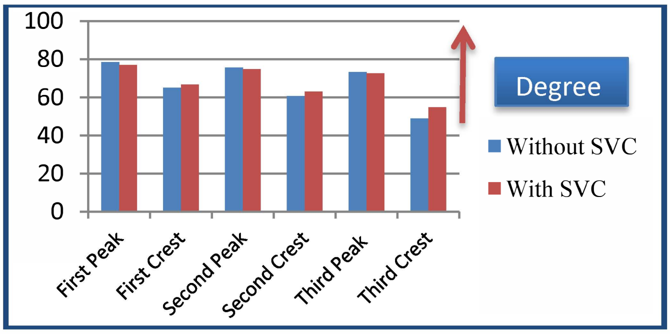

Fig.17 Swing Curve of Power Plant Without and With SVC

V RESULTS AND ANALYSIS

The values of voltages in Fig.14 and Fig.15 clearly indicate that the bus voltage dip at 400 kV GSS and 220 kV GSS is less if SVC is installed in the power system as compared to without SVC installation. It is also clearly depicted that the improvement in voltage dip is highest in GSS where the SVC is installed. The results also indicate that the improvement in voltage in system/bus voltage is in reverse ratio of distance from the point of installation of SVC. In nearer the GSS; nearer from the point of SVC installation more improvement is seen. Fig.16 depicts the results that with and without SVC installation with the sudden increase of wind power, the improvement in flow of active power in transmission lines is less or nil, but reactive power flow in transmission lines is increased as per requirement of the system due to injection or absorption of reactive power by SVC. The transient condition performance of conventional power plant as shown in Fig.17 depicts the pacification of swing curve peaks with SVC as compared the results without SVC[10-11]. It is very important to analyze the bus voltages under extreme load conditions under steady state operation of the power system. These conditions can be visualized by a maximum load with full wind power and minimum load with minimum wind power and also considering the without and with SVC conditions.The effect on the bus voltage on all the buses covered in high wind power penetration area is given in Fig.18.

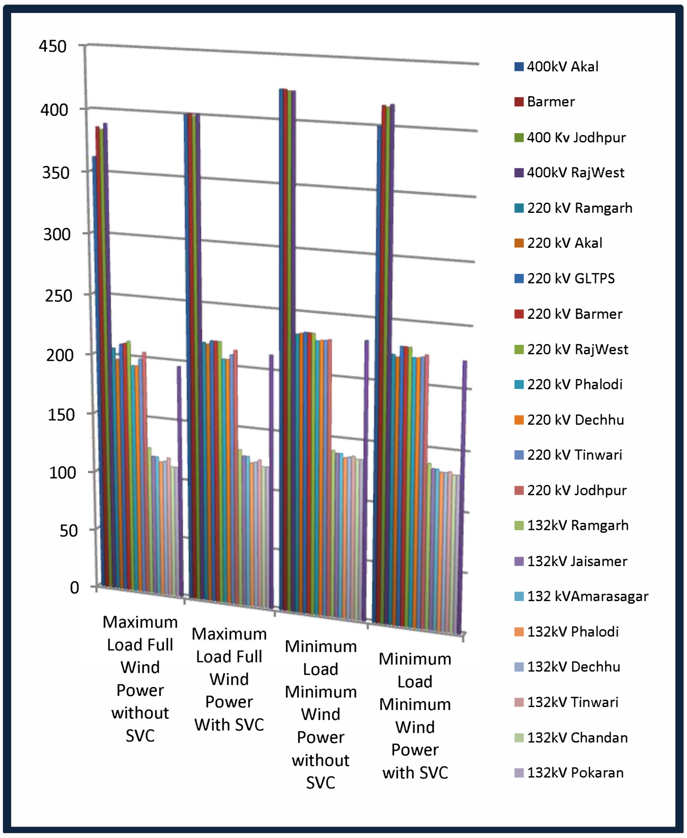

Fig.18 Various Bus Voltages in Western Rajasthan Without &With SVC

It is observed that SVC is improving the bus voltages in both the extreme conditions and bringing back the bus voltages near the normal values.The improvement is less in far away bus and power station buses. These results indicate that there is the requirement of SVC in Western Rajasthan to operate the power system smoothly.

VI CONCLUSIONS

A lot of wind power variability is observed in the Western part of Rajasthan. Wind power penetration in this area is also affecting the power system operation. The analysis is performed on Mi-Power software, with real time data of Western Rajasthan with consideration of SVC installation at wind power zone. On analysis, it is observed that the Static Var Compensator supports in mitigating voltage and reactive power requirement of wind farms. It avoids the tripping of transmission lines due to overvoltage condition by absorbing reactive power. The SVC supports the bus voltage in steady state and transient conditions by providing static and dynamic var. The proper size and location of SVC is important due to its role for maintaining the voltage and mitigating requirement of reactive power. In the case of Western Rajasthan Grid having high wind power penetration area, the ± 500MVAr capacity of SVC is required to be installed at main wind bus at Akal.

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