Wind Farm Voltage Drop Stabilisation Using SVC Inverter Based on FACTS

Souheyla Benachour[1,*], *Omar Bendjeghaba*[2]

[1] Department of Process Automation and Electrification, INH, University M'Hamed Bougara of Boumerdes, 55 avenue de l'indépendance,35000, Boumerdes, Algeria
[2] LREEI, faculty of hydrocarburs and chimie, University of Boumerdes Boumerdes, Algeria
[*]Corresponding author Email: so.benachour@univ-boumerdes.dz

Article Info

Article history:

Received 03 December 2019
Revised 20 May 2020
Accepted 03 June 2020

Keywords:

FACTS
SVC
Voltage stability
Wind farm
CPF

ABSTRACT

The study focus on maintain of voltage factor in the near-unity network (1pu) using a Static Variables Compensator (SVC). In order to determine the effectiveness of this device to improve the stability of a power system with distributed genetartion in presence of wind farm based on MADA, the power flow is calculated without the existence of the SVC at first, and then when the SVC is integrated. This operation is performed to make a comparison and evaluate the role of the device in the system. However, in order to improve voltage stability as well as minimize power losses for practical power systems, it is important to locate the appropriate place of SVC. Various methods have been developed. The particular CPF method has been proven effective in determining SVC placement. The obtained results are discussed and analysed, it is found that this device provides a considerable reduction in the voltage drop and appreciable control of the voltage at the concerned busbar.

I. Introduction

The primary factors for which the consumption of electrical energy is steadily increasing are the growth of population and industrialization. Thus, to have a balance between production and consumption, it is first necessary to increase the number of power plants, lines, transformers… etc., which implies an increase in cost and environmental degradation. Consequently, it is now important to have mesh networks and work close to the stability limits to meet these new requirements [1-6]. Due to the environmental concerns, renewable energy sources such as wind or solar generation have gained the popularity in the recent years [2].

The wind energy is one of the most significant and rapidly developing renewable energy sources in the world and it provides a clean energy resource, which is a promising alternative in the short term in Algeria. [7-8]

The electric power supplier is working to ensure the quality of electric power, to get to increase service continuity, now the quality criteria have evolved with the development of electronic equipment, which takes a prominent place in the production, and transport of an electrical network. It will, in the future, complete their action by implementing electronic power devices at high speed response, recently developed and known by the name FACTS (Flexible Alternative Current Transmission System) for control networks [5].

FACTS systems (Flexible Alternative Current Transmission Systems) are fast control systems networks using the resources offered by the power electronics and control microelectronics were recently studied and realized [6-11]. The recent development of FACTS devices opens up new possibilities for more efficient network operations by continuous and rapid action on the various network parameters (phase, voltage, impedance). Thus, power flows can be better controlled and better kept tensions, which will increase stability margins or tender to the thermal limits of the lines. Generally, the main role of FACTS devices is the compensation of the electric power to the inside [3-6].

- The problem of power loss, voltage drops.
- The optimization of power flow (Dispatching).
- The voltage stability. [9-11]

To increase cost and environmental degradation, the use of renewable energy sources such as wind conversion chains or solar farms is a premery interest in the modern network structurs, for that our study integrate the presence of a wind farm as supply connected to the network to show it influence in voltage drop over the network bus bars and the reaction of the SVC installation after determin the effecace emplacement.

II. STATIC VAR COMPENSATOR (SVC):

The Static Var Compensator (SVC) is a parallel reactive compensation equipment with electronic power base capable of reacting in some cycles to network changes. It allows among others the connecting remote production center expenses and decreases the effects of defects or load fluctuations. The SVC controls the voltage on its terminals order the amount of reactive power is injected or absorbed in the power system [10]. When the system voltage is low, the SVC develops reactive power (SVC capacitive). When the system voltage is high, it absorbs reactive power (SVC inductive).

$$P_{G,i} - P_{D,i} = V_i \sum_{i=1}^{b} \left[V_j \left[G_{ij} \cos\left(\delta_i - \delta_j\right) + B_{ij} \sin\left(\delta_i - \delta_j\right) \right] \right] \quad (1)$$

$$Q_{G,i} - Q_{D,i} = V_i \sum_{i=1}^{b} \left[V_j \left[G_{ij} \sin\left(\delta_i - \delta_j\right) + B_{ij} \sin\left(\delta_i - \delta_j\right) \right] \right] \quad (2)$$

Where PG,i and QG,i are the active and reactive generating powers at the ith bus; PD,i and QD,i are the active and reactive of demand powers at the ith bus. Gij and Bij represent the real and imaginary components of element Y'ij of the admittance matrix.

Association of TCR devices, TSC, fixed capacity benches and harmonic filters is the hybrid compensator, better known under the name SVC (Figure 1) [4], the first example was installed in 1979 in South Africa.

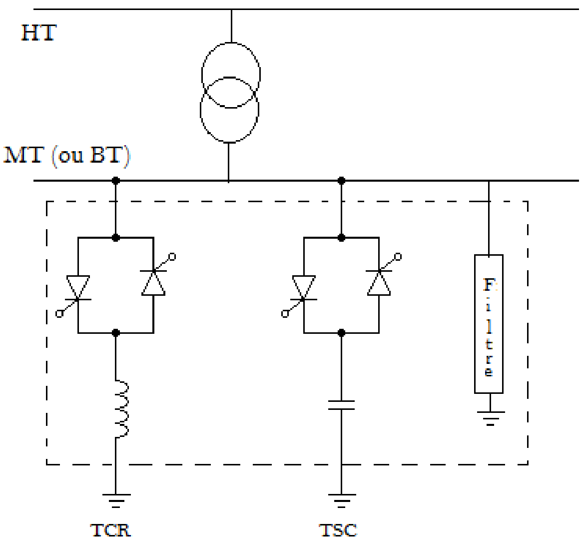

Figure 1. SVC (Static Var Compensator).

The static characteristic is given in Figure.2 [5].

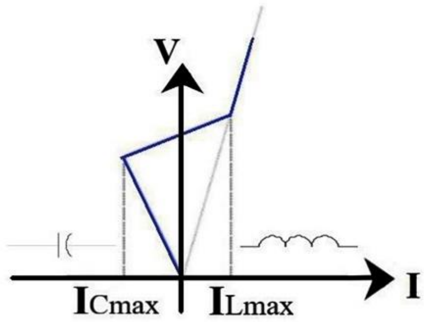

Figure 2. Characteristic of an SVC.

In this characteristic, we can distinct three areas [12]:

- An area where only the capacities are connected to the network.
- A control area where the reactive energy is a combination of the TCR and TSC.
- An area where the TCR gives its maximum energy (control stop), the capacitors are disconnected.

III. CONTINUATION POWER FLOW METHOD

The purpose of this method is to acquire a continuum of power flow solution for a specific load change scenario. As can be seen in Figure 3, the procedure starts from a known solution then predicts a subsequent solution for a different value of the load parameter.

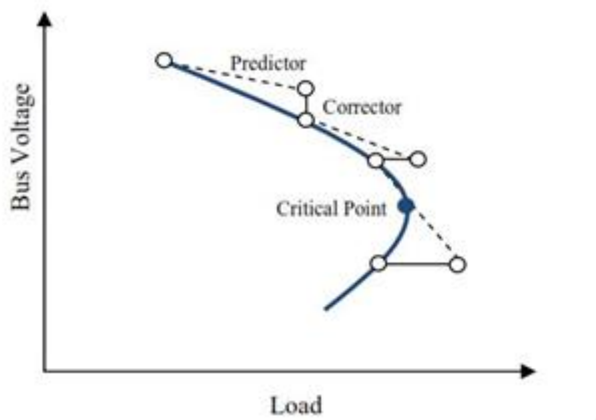

Figure 3. Predictor-corrector scheme of the continuation power flow [15].

IV. Description of the system

This simulation is done on 14 bus system with base MVA=100 and the data [14] is taken for the standard IEEE 14 bus system. The test system is shown in Figure.4 which includes total 14 bus in which 14 bus bars, 5 generators including PV and wind generators, 11 loads, and 20 transmission lines. This simulation model is made in PSAT/MATLAB software.

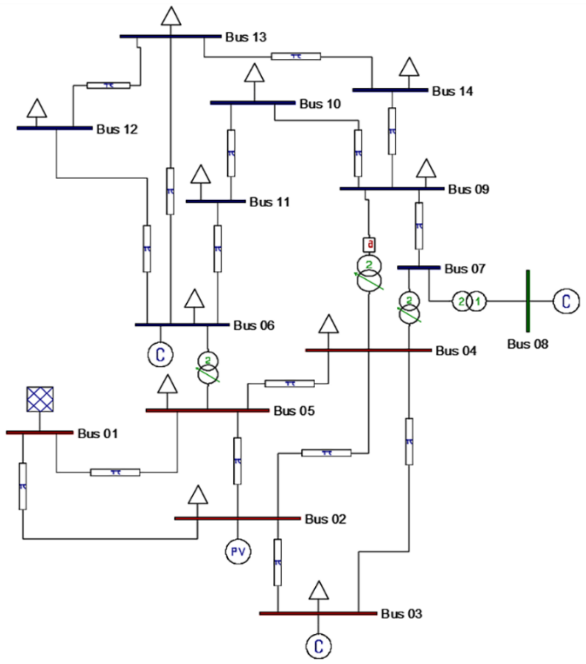

Figure 4. 14 bus bars network.

V. SIMULATION RESULTS

A test network of 14 bus bars, Figure 4, has been employed in PSAT/MATLAB program to find out the performance of SVC in increasing the flow of active and reactive power.

The power flow is calculated by the conventional method (Newton-Raphson). Results are shown in table.I.

TABLE I: Voltages and angles of 14 bus bars network

BUS BAR NUMNER	*PSAT*	
	voltage VM (pu)	***Angle (deg)***
1	1.06	0
2	1.045	-7.7717
3	1.01	-19.0201
4	0.9975	-15.125
5	1.0024	-13.0138
6	1.07	-13.0138
7	1.0349	-20.7153
8	1.09	-20.7153
9	1.0117	-23.5476
10	1.0112	-23.8017
11	1.0351	-23.4123
12	1.0461	-23.9261
13	1.0364	-23.9967
14	0.99617	-25.2386

V.1. Simulation results of the system without compensation

The calculation of the continuous power flow method (CPF) determines the amplitude of the voltages at the 14 bus bars with the increase of the load, which makes it possible to identify the sensitive bus bars (which has an inadmissible drop), obtained Results after simulation are shown in Table. II and figure 5.

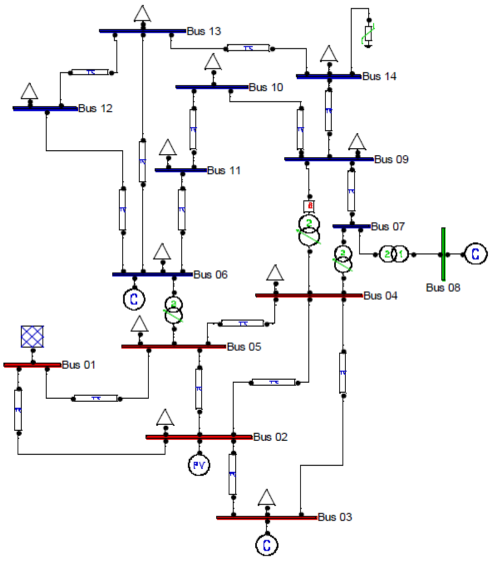

Figure 5. Integration of a SVC at busbar n°14 in a network of 14 busbars.

The calculation of power flow has been effected with Newton-Raphson method, the results are obtained through PSAT.

TABLE II: Voltages and angles of 14 bus bars network without SVC

BUS BAR NUMNER	*PSAT*	
	voltage VM (pu)	*Angle (deg)*
1	1.06	0
2	1.045	-36.1848
3	1.01	-84.6673
4	0.69334	-69.6366
5	0.67636	-58.9401
6	1.07	-111.0293
7	0.79186	-95.784
8	1.09	-95.784
9	0.70174	-108.7289
10	0.72569	-111.2236
11	0.87853	-111.6237
12	0.97837	-114.8097
13	0.92969	-114.7377
14	0.68902	-119.3869

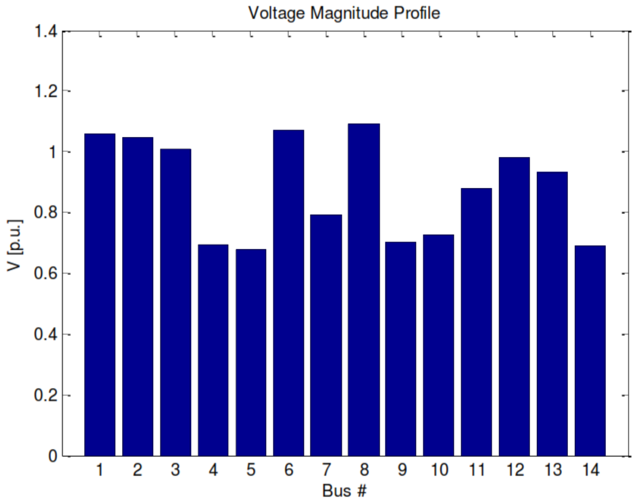

Figure 6. Voltages of 14 bus bars network without SVC.

According to the fig. 6, six bars are identified sensitive, which are bus (4), bus (5), bus (7), bus (9), bus (10), and bus (14).

The evolution of each voltage of these bus bars in function of power (P-V curve) is shown in the figure 7; the voltage sensitivity margin corresponds to the maximum load.

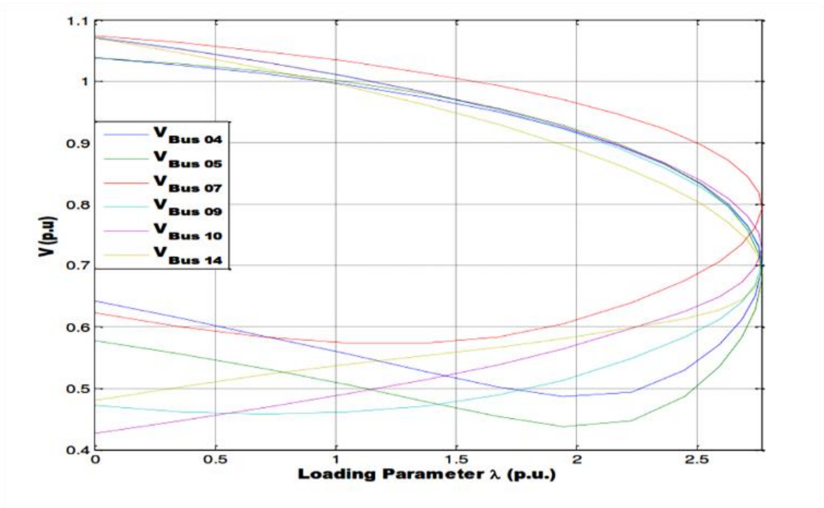

Figure 7. P-V curves of sensitive bus bars.

From the curves P-V (fig. 6), the analyzed network has a margin of λ = 2, 7699

V.2. Simulation results of the system using Static Var Compensator (SVC)

After having calculated the power flow in the network (14 bus bars), without the presence of the SVC element, the case of integration of a single SVC is treated, the SVC is connected to the bus bar number 14. Because it is the most sensitive among the bus bars affected because of the increase of the load, it presents a voltage of V= 0.68902 pu.

The calculation of power flow has been effected with Newton-Raphson method after the SVC insertion, the results are obtained through PSAT. The table III illustrates these results.

TABLE III: Voltages and angles of 14 bus bars network with SVC

BUS BAR NUMNE R	***PSAT***	
	voltage VM (pu)	***Angle (deg)***
1	1.06	0
2	1.045	-4.9999
3	1.01	-12.7822
4	1.011	-10.2416
5	1.0157	-8.7526
6	1.07	-15.1508
7	1.0462	-13.5205
8	1.09	-13.5205
9	1.0265	-15.1814
10	1.0266	-15.4582
11	1.0445	-15.4182
12	1.0509	-15.9538
13	1.0423	-15.8872
14	1.0000	-16.1481

As shown in the table 3 the integration of the SVC at the bus bar number 14 provides a considerable improvement in the voltages.

The continuous power flow (CPF) analysis in the case of the presence of an SVC gives the P-V curves shown in the figure 8.

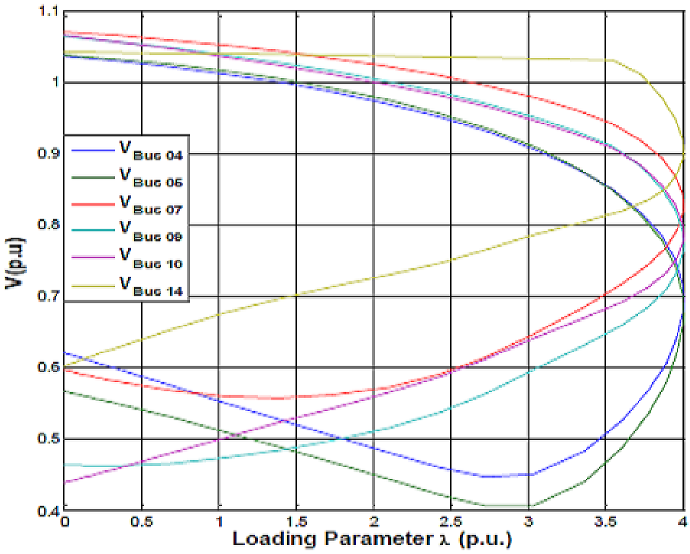

Figure 8. P-V curves of sensitive bus bars.

It can be seen that the voltage stability margin is significantly improved with λ = 4.0017.

VI. CONCLUSION

The shunt compensation is essentially intended for the adjustment of the voltage of bus bars of network contien decentralised renouvlabe sources, as wind farm based on MADA, connected to the network via a power inverter. The static compensator of the reactive power (SVC) can contribute very effectively to maintain the voltage plane in an acceptable margin (1pu). Therefore, we conclude that by connecting the SVC in the optimal location, using the Newton–Raphson method and the PSAT of MATLAB, we get the best improvement in term of stability margin the voltage, and maximum reduction of system active and reactive power losses.

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