Ultc and Statcom Coordinated Contrl to Reduce Statcom Capacity

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Article Info
Page Number: 268-277
Publication Issue:
Vol. 71 No. 1 (2022)

Article History
Article Received: 02 February 2022
Revised: 10 March 2022
Accepted: 25 March 2022
Publication: 15 April 2022

Abstract: This paper presents a new scheme for cooperation between ULTC and STATCOM. Both devices are generally used to control the voltage and reactive power in network. The STATCOM, unlike ULTC is characterized by its fast response so equal of dynamic voltage control and also giving reactive power in emergency situations. If the control action of these two devices isn't coordinated, the STATCOM will fast response to reactive power demand due to its improved operating speed. Thus, the capacity of STATCOM will be completely employed and so cannot have important contribution in emergency situations. In this paper, by making some variations in the control system of STATCOM and creating a variable reference voltage, a new and simple scheme is produced to coordinate STATCOM and ULTC. Based on the proposed scheme the capacity of STATCOM is reduced hence some compensation circumferences delivered for control purposes in emergency situations. The main advantage of the presented approach is that only the STATCOM control system is modified to some extent but that of the ULTC is left unchanged. The simulation results demonstrate the precision and capacity of the proposed system.

Keywords- Coordinated control, STATCOM (Static Synchronous compensator), ULTC (Under load tap changing transformer).

I. INTRODUCTION.

In recent years, to improve the efficiency of modern power systems and also to enhance the power quality the FACTS devices are widely used [1]. The static synchronous compensator (STATCOM) is the most promising shunt connected FACTS device for controlling voltage and reactive compensation with the capability of fast reaction. On the other hand, the under load tap changing transformer (ULTC) is a slow and discrete functioning electromechanical voltage control device. When a bus voltage is controlled by such regulators problems arise due to their different characteristics. One problem is related to issue of interacting with other power system components. Another problem is emanated from the lack of coordination between ULTC and STATCOM. Due to the presence of non-linear components and delayed operation, the structure of ULTC becomes complicate in adjusting the voltage in power systems [2]. Voltage regulation, advancementof transient stability and mitigating power fluctuations arethree main tasks of STATCOM in a power grid (1).STATCOM is a fast response device in compare with ULTC.In conventional control approaches, two devices act individuallyand don't communicate with each other. Hence, IfSTATCOM is connected to the system in the vicinity of theULTC, it'll quick respond to reactive power demand eithergenerating or absorbing so its whole capacity is used up.Consequently, this device doesn't have enough capacity foremergency situations (3). Hence, applying the coordinatedcontrol in the performance of these two devices is necessary.Different approaches have been proposed to establish acoordination between the ULTC and STATCOM. In (3), theartificial neural network (ANN) is used to give coordinationbetween two devices. In the system presented in this paper,STATCOM first responds to reactive power demand, alsousing the ANN the reactive power output of STATCOM isminimized and the optimal tap position is acquired and appliedto ULTC. In the system presented in (4), using a regulator, thereference voltage of ULTC is determined according to theSTATCOM output. In the structure of this controller, a nonlinear dead zone block is used to help oscillatory operation around the required operating point. In(5), a new system for coordinating STATCOM with other devices i.e. ULTC and capacitor is presented. In (6) a comprehensive system for coordinating the fast control devices SVC and STATCOM with slow ones (ULTC and capacitor) is provided. In (7) a coordinated control scheme is proposed to reduce the needed capacity of STATCOM. In the proposed scheme of this reference, the STATCOM is actuated only when the controlled voltage exceeds a required band. References(8) and(9) also suggest ways to establish coordination between ULTC and SVC using different approaches. According to below mentioned references various methods are employed to set coordination between slow and fast voltage control systems to enhance their performance. In the present paper in the following section, at first the proposed scheme for the coordination will be explained and also, its efficiency and effectiveness will be demonstrated by performing simulations on a sample network. The special features of the proposed system are also mentioned in same section.

II. PROPOSED SCHEME

In this paper, based on the proposed scheme, STATCOM isprimarily allowed to give rapidly the required reactive power. As shown in Fig. 1 in which the operating point on the STATCOM V- I characteristic moves from a point 1 to a point 2. Also, by making a proper change in the STATCOM reference voltage, the operating point returned to point 3, there by the STATCOM capacity is slowly released, and during this process, the ULTC can be forced to deliver reactive power by changing its tap.

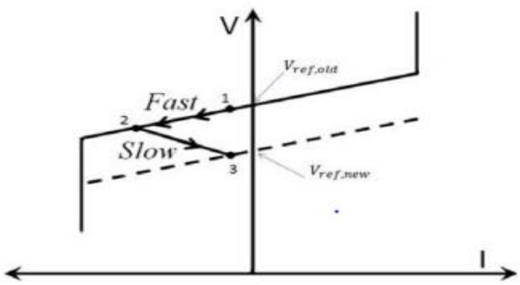

Figure 1. Movement of operating point along STATCOM

In this way, the operating point will be slowly moved from a point 2 to 3. The reactive power at an operating point 3 is equal to that of the first operating point. The quantity of this reactive power should be determined in such a way that the STATCOM could have sufficient operated margin for emergency situations. To apply the proposed scheme, a proportionate controller is used as shown in Fig. 2.

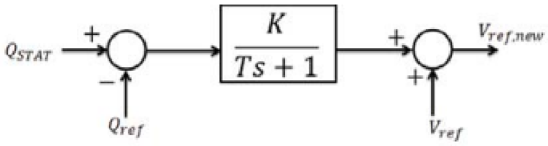

Figure 2. Proposed proportional controller

Figure 2. Proposed proportional controllerthe proportionate controller is responsible for amplifying the error signal and causing the necessary detention. According to 2, the reference voltage will change slowly in such a way that the output power of STATCOM is maintained around the reference value. As long as the ULTC has not reached the bottom or top of its own tap position, the STATCOM provides fast the needed reactive power and also by making a proper change in its reference voltage, the ULTC takes the responsibility of supplying the reactive power. In situations where the ULTC has reached the bottom or top of its own tap position, using the variable reference voltage for STATCOM is not proper and leaded to passing over the required band. Thus, the tap position of ULTC should be transferred to control system of STATCOM until the proper reference voltage (fix or variable) is used according to tap positions. The accomplishment of proposed scheme on a system including ULTC and STATCOM is shown in Fig. 3.

As shown in this figure, in the proposed control scheme, only the control system of STATCOM is changed and that of ULTC left unchanged. The Key points of proposed scheme are summarized as Follows:

1. As long as the ULTC has not reached the bottom or top of its own tap position, the variable reference voltage is produced by the system control of STATCOM.
2. If the ULTC has reached the bottom or top of its own tap position and the controlled voltage (V2) passes over the down or up- setting threshold, the variable reference voltage is replaced by a fix one
3. Down and upsetting thresholds are named in control range of ULTC.
4. Down and up fix reference voltages should be selected in manner that the voltage magnitude is kept in the asked range. Thus, down fix reference selects a value slightly bigger than down setting threshold and up fix reference selects a value slightly Lower than upsetting threshold.
5. The transformation from the fix voltage reference to variable voltage reference is done when the STATCOM output is returned back to reference value(Q_{ref}).

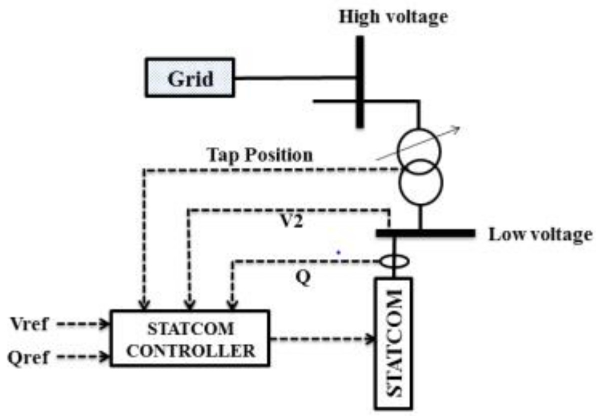

Figure 3. Implementation of proposed scheme

III. SIMULATION RESULTS

In an order to estimate the capability and exactness of the proposed scheme, the modified 9 bus WSCC test system is assumed in Matlab/ Simulink software. The system data are taken from 10), other required data and Study system model in Matlab/ Simulink are establishing in Appendix. As mentioned earlier reducing the demanded STATCOM capacity and hence reserving a compensation circumference for crisis situation while maintaining the voltage magnitude of bus 10 close to 1 per-unit are objectives of the proposed coordination scheme. In this simulation it has assumed that the cargo variations are within a range of 80 to 140 of its nominal value in 24- hour time interval. a day-to-day lading curve is shown in Fig. 4.

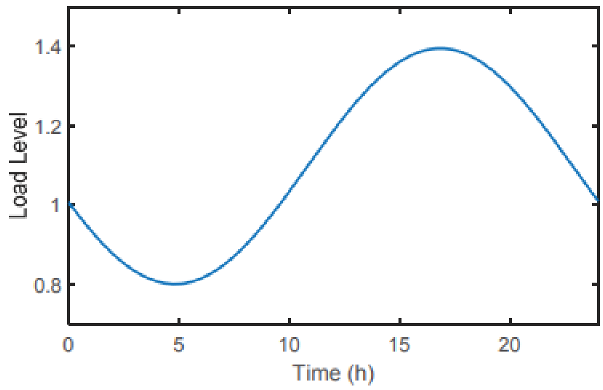

Figure 4. Daily load curve

Fig. 5 shows the single line illustration of test system. In modified test system the ULTC is installed between bus 8 and bus 10. Bus 10 corresponds to the low voltage side of the ULTC. Thus, bus 10 is the controlled- voltage bus. The simulation is performed in 24- hour interval and the results are shown in two modes 1. Without coordination 2. With coordination.

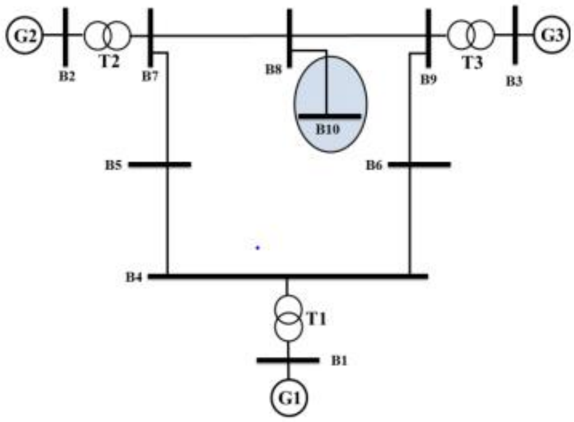

Figure 5. Modified WSCC 9 Bus test system

Fig. 6 shows that how the ULTC changes in two uncoordinated and coordinated modes. As seen in this figure, in uncoordinated mode, the STATCOM fast responds to voltage variations and provides the reactive power necessitated (positive or negative), so the ULTC tap is practically constant during the simulation period. However, in coordinated mode, the ULTC is forced to supply the needed reactive power, so its tap movements are significant.

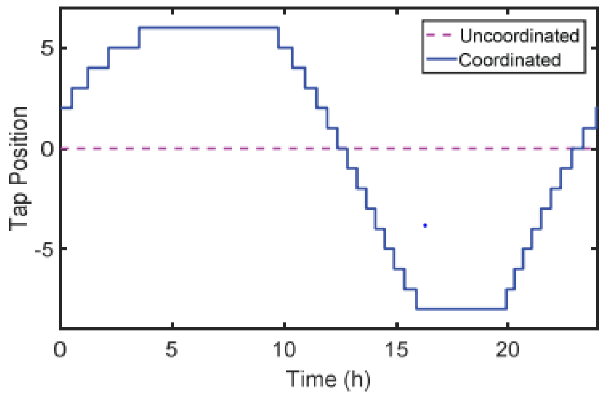

Figure 6. Tap Movements

As stated, the main purpose of the ULTC is to stabilize voltage magnitude of controlled-bus (V2) close to 1 per-unit. In uncoordinated mode, STATCOM rapidly responds to load variations (increase or drop) to prevent voltage changes by supplying the necessitated reactive power. In the coordinated mode, STATCOM firstly responds to the demand of reactive power to prevent voltage changes, also the reference voltage of STATCOM is appropriately modified and the output reactive power of STATCOM decreases and rather the ULTC forced to supply necessitated reactive power by proper tap movement. Fig. 7 shows the voltage variation in a bus 10. As shown in this figure, the coordinated mode is significant comparable to uncoordinated mode and the voltage profile is always close to 1 per-unit.

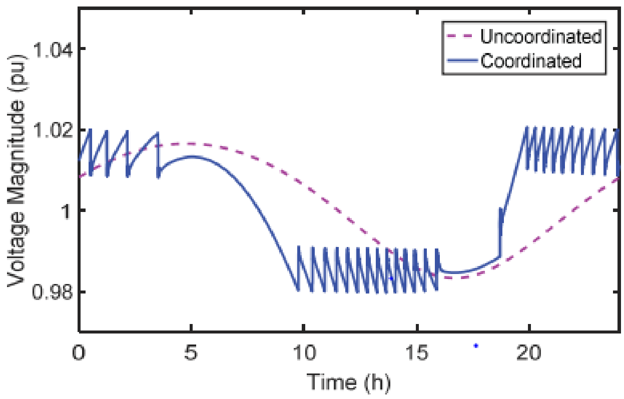

Figure 7. Controlled-bus voltage variation

The reactive power variation of STATCOM is shown in Fig. 8 and the reference voltage of STATCOM in uncoordinated and coordinated mode is shown in Fig. 9.

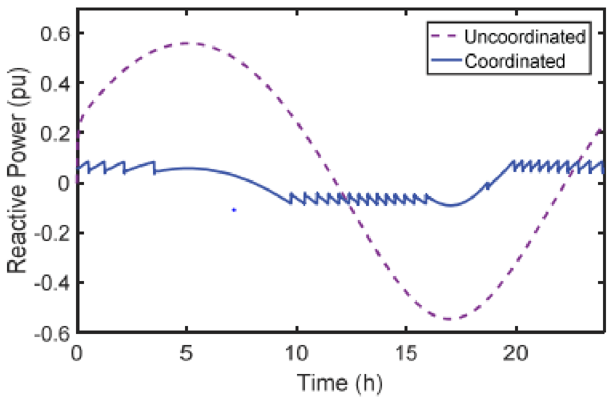

Figure 8. Output reactive power of STATCOM

In the proposed scheme, the reference reactive power is assumed to be zero. Thus, after a short period of time, the supply of reactive power is done by changing the tap of ULTC and releasing the STATCOM capacity. As seen in Fig. 8, in coordinated mode, unlike the uncoordinated mode, the reactive power output is always close to reference value. Hence, there's always enough free capacity for crisis conditions. As seen in fig. 9, the changes of reference voltage in coordinated mode is such that the STATCOM output is close to reference value.

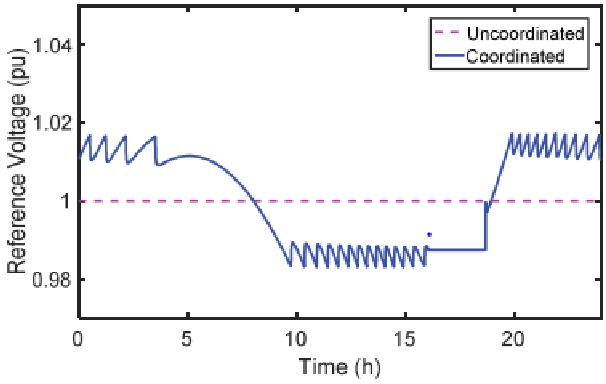

Figure 9. Reference voltage of STATCOM

In an order to estimate the efficiency of the proposed scheme regarding the reduced capacity of STATCOM, the test system is replaced with new STATCOM is having half capacity and the simulation is carried out. Tap movement of ULTC in two uncoordinated and coordinated modes is shown in Fig. 10. Due to reduce capacity of STATCOM, unlike Fig. 6, tap movement of ULTC in uncoordinated mode is not zero. As shown in this Figure, in coordinated mode the ULTC is forced to have further tapped movement to give the needed reactive power. The voltage variations of controlled-bus in uncoordinated and coordinated modes are shown in Fig. 11. This Figure illustrates that by proper excitation of reactive power with STATCOM and ULTC in coordinated mode, voltage magnitude of controlled-bus is remained within permitted range.

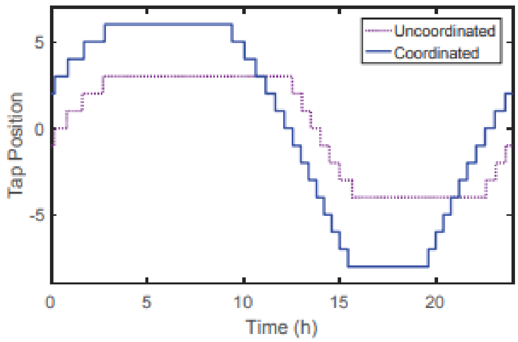

Figure 10. Tap movements

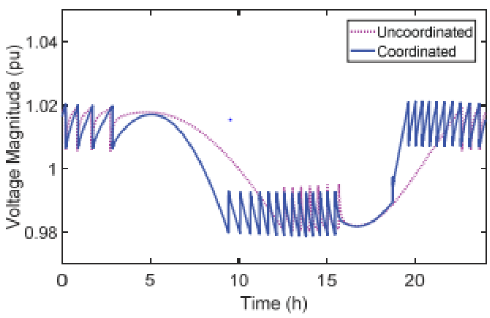

Figure 11. Cotrolled-bus voltage change

The reactive power variation of STATCOM in uncoordinated and coordinated modes is shown in Fig. 12. As seen in this figure when the ULTC has reached the bottom of its own tap position, the STATCOM has further donation in supplying reactive power and maintaining voltage magnitude of a bus 10 close to 1 per-unit. Although STATCOM provides more reactive power in this situation, but its output reactive power in comparison with the uncoordinated mode is negligible, hence, a considerable circumference is reserved.

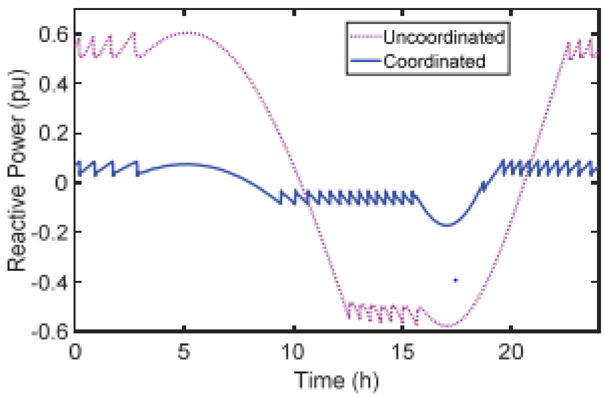

Figure 12. Output reactive power of STATCOM

The reference voltage of STATCOM in uncoordinated and coordinated modes is shown in Fig. 13. In this figure analogous to Fig. 9, reference voltage applies to STATCOM only in small interval fix.

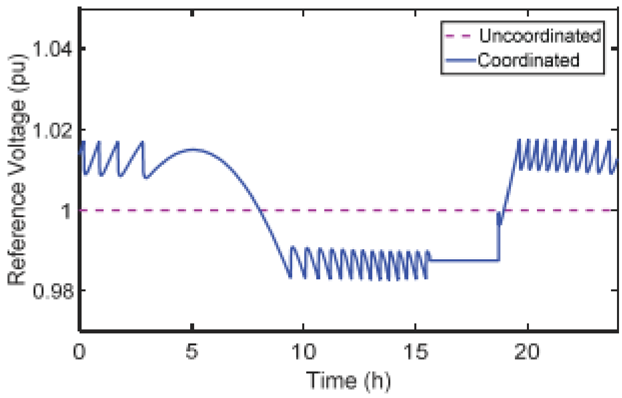

Figure 13. Reference voltage of STATCOM

IV. CONCLUTION

In this paper, a new scheme is proposed to make coordination between ULTC and STATCOM. In the proposed scheme, STATCOM supplies reactive power only in situations where ULTC cannot deliver it. Hence, STATCOM always has some free capacity which can be used for necessary conditions. This indicate that the needed STATCOM capacity is reduced. The simulation results on the modified WSCC test system demonstrate the capability of the proposed scheme to provide a proper coordination between these two devices. The proposed system in this paper has the followed features:

1. Modifying control system of STATCOM without making any changes in ULTC control system.
2. Reserving acceptable circumference for using in necessary situations by limiting the STATCOM output.
3. Keeping the magnitude of voltage at controlled-bus within a required range.
4. Economic operation of STATCOM via reducing its needed capacity.
5. Simplicity and ease of implementation. Pertaining to above mentioned advantages, it can be concluded that the proposed coordination scheme is simple, effective and relatively feasible in compare with other proposed approaches.

V. REFERENCES

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VI. APPENDIX

A. ULTC transformer data:

• Turns ratio step 0.0185 pu;

• Number of taps 17;

• Time delay 5 min;

• Regulator dead band 0.02 p.u;

B. STATCOM data:

• STATCOM rating 100 MVA;

• Inductive and capacitive;

• droop 0.03 pu;

C. Controller data:

• Vref=1 pu and Qref=0 ;

• T=100 s and K=0.2;

• Down setting threshold 0.985 pu;

• Up setting threshold 0.995 pu;

• Down fix reference 0.9875 pu;

• Up fix reference voltage 0.9925 p.u;

D. Study system model in Matlab/Simulink (Fig. 14)

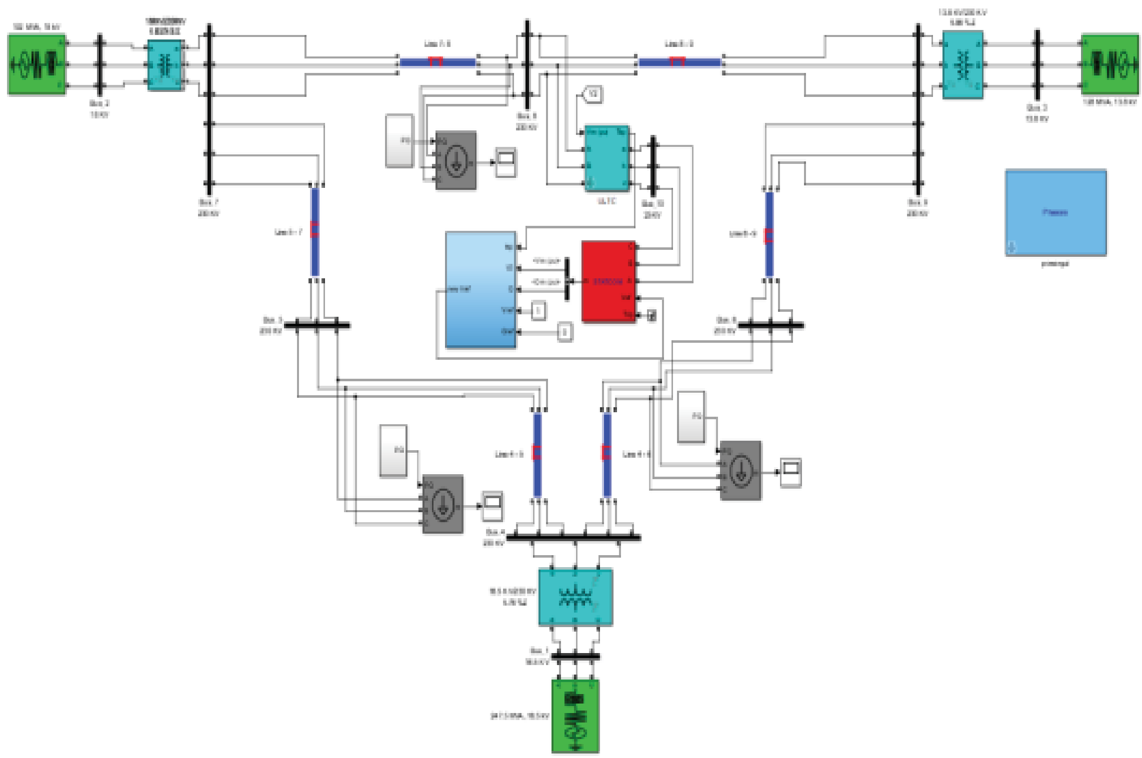

Figure 14. Study system model in MATLAB/SIMULINK