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A Comparison between Electric springs and STATCOM For Distributed voltage control

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Abstract

The concept of electric spring (ES) has been proposed as of late as a powerful methods for appropriated voltage control. The thought is to control the voltage over the basic (C) loads while permitting the noncritical (NC) impedance-type loads (e.g.,water radiators) to change their energy utilization and in this way add to request side response. In this paper, a correlation is made between dispersed voltage control utilizing ES against the conventional single point control with Static Compensator (STATCOM). For a given scope of supply voltage variety, the aggregate receptive limit required for every alternative to create the desired voltage control at the point of association is thought about. A straight forward contextual investigation with a single ES and STATCOM is presented first to demonstrate that the ES and STATCOM require practically identical receptive energy to accomplish comparable voltage control. Examination between a STATCOM and ES is additionally substantiated through comparative contextual analyses on the IEEE 13-transport test feeder framework and further more on a piece of the dissemination arrange in Sha Lo Wan Bay, Hong Kong. In the two cases, incidentally a gathering of ESs achieves preferred aggregate voltage direction over STATCOM with less general receptive power limit.Dependence of the ES capacity on extent of basic and NC stack is additionally appeared.

INTRODUCTION

Voltage control in medium voltage (MV) or low voltage(LV) circulation systems is normally practiced through transformer tap-changers as well as exchanged capacitors/reactors.Sometimes a Static Compensator (STATCOM) is utilized for quick and exact voltage direction, especially for the touchy/basic loads [1].

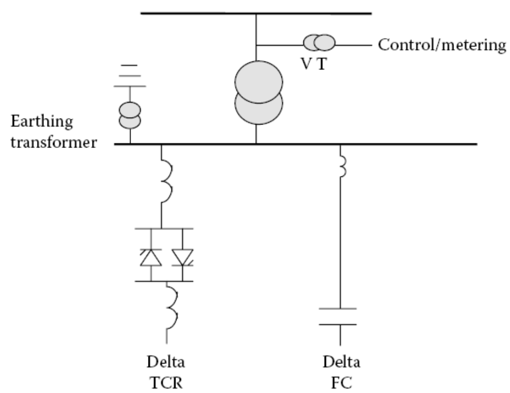
The novel concept of electric spring (ES) has been proposed as a viable methods for conveyed voltage control [2].The thought is to direct the voltage over the basic loads while allowing the noncritical (NC) impedance-type loads(e.g., water warmers) to fluctuate their energy utilization and in this way add to request side response [3], [4] too. This would allow and encourage extensive entrance of intermittent sustainable power sources without requiring enormous measures of vitality stockpiling to go about as a support amongst free market activity [5]. The essential evidence of concept of ES has just been exhibited through equipment experimentation with the created proto types[2], [6]. Conveyed voltage direction through aggregate activity of a bunch of ESs, each employing hang control has additionally been delineated [7]. In this paper, the concentration is to look at the effectiveness of single point voltage control using STATCOM against appropriated voltage control using a gathering of ESs.

The reason for examination is add up to voltage direction [root mean square of the deviation of the real voltages from the appraised (1.0 p.u) values] accomplished and the general receptive capacity required for every choice with a specific end goal to accomplish that [8], [9]. Various papers [2], [5]–[7] have been distributed as of late on the ES concept and its control. In any case, none of those papers have concentrated on the aggregate performance of different of ESs considering practical conveyance systems. This paper demonstrates the effectiveness of different ESs working as one through contextual analyses on an IEEE test feeder arrange and furthermore a piece of a genuine dissemination framework in Hong Kong. The voltage direction performance and aggregate receptive power prerequisite of a gathering of ESs if there should be an occurrence of circulated voltage control is looked at against the single-point control using a STATCOM. In the two cases, surprisingly a gathering of ESs achieves preferable aggregate voltage control over STATCOM with less general receptive power limit.

SVC

SVC USING A TCR AND AN FC:

In this plan, at least two FC (settled capacitor) banks are associated with a TCR (thyristor controlled reactor) through a stage down transformer. The rating of the reactor is picked bigger than the rating of the capacitor by an amount to give the maximum lagging vars that must be ingested from the framework. By changing the firing point of the thyristor controlling the reactor from 90° to 180°, the responsive power can be shifted over the whole range from maximum lagging vars to leading vars that can be consumed from the framework by this compensator.



SVC of the FC/TCR type:

The main hindrance of this setup is the critical music that will be created due to the halfway conduction of the expansive reactor under typical sinusoidal consistent state operating condition when the SVC is absorbing zero MVAr. These music are sifted in the following way. Triplex music are canceled by arranging the TCR and the optional windings of the progression down transformer in delta association. The capacitor keeps money with the assistance of series reactors are tuned to channel fifth, seventh, and other higher-arrange sounds as a high-pass channel. Promote losses are high because of the circulating current between the reactor and capacitor banks.

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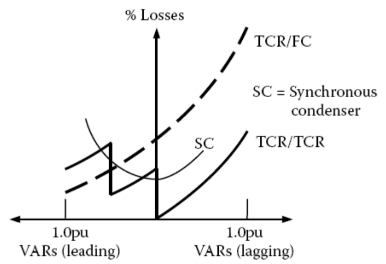
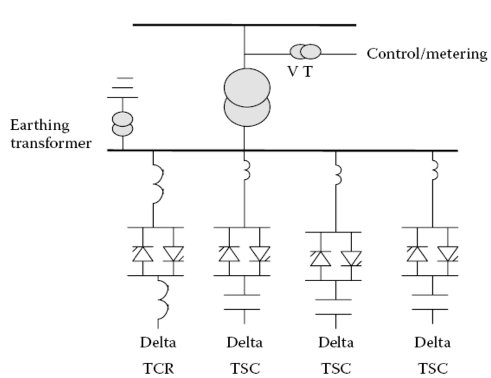


Comparison of the loss characteristics of TSC–TCR, TCR–FC compensators and synchronous condenser. These SVCs do not have a short-time overload capability because the reactors are usually of the air-core type. In applications requiring overload capability, TCR must be designed for short-time overloading, or separate thyristor-switched overload reactors must be employed.

SVC USING A TCR AND TSC:

This compensator overcomes two major shortcomings of the prior compensators by reducing losses under operating conditions and better performance under expansive framework disturbances. In perspective of the littler rating of every capacitor bank, the rating of the reactor bank will be 1/n times the maximum yield of the SVC, along these lines reducing the sounds produced by the reactor. In those circumstances where music must be diminished further, a little amount of FCs tuned as channels might be associated in parallel with the TCR.



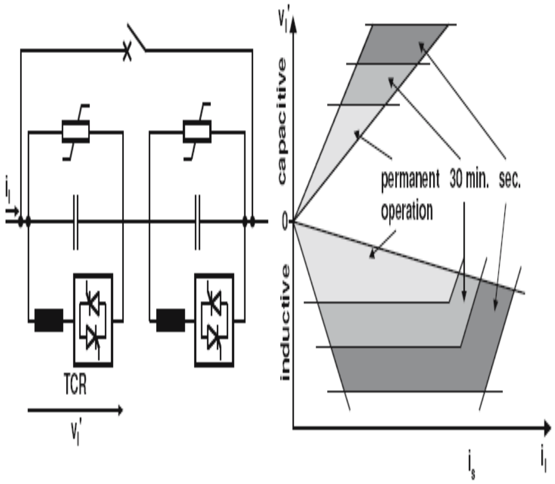
SVC of combined TSC and TCR type

At the point when expansive disturbances happen in a power framework because of load dismissal, there is a plausibility for vast voltage homeless people on account of oscillatory interaction amongst framework and the SVC capacitor bank or the parallel. The LC circuit of the SVC in the FC compensator. In the TSC–TCR conspire, because of the adaptability of fast switching of capacitor banks without apparent disturbance to the power framework, motions can be kept away from, and hence the homeless people in the framework can likewise be maintained a strategic distance from. The capital cost of this SVC is higher than that of the prior one because of the increased number of capacitor switches and increased control multifaceted nature.

TCSC:

Thyristor Controlled Series Capacitors (TCSC) address particular dynamical issues in transmission frameworks. Right off the bat it increases damping when extensive electrical frameworks are interconnected. Besides it can conquer the issue of Sub Synchronous Resonance (SSR), a wonder that involves an interaction between huge warm generating units and series remunerated transmission frameworks. The TCSC's fast switching capacity provides a component for controlling line control flow, which licenses increased loading of existing transmission lines, and allows for quick rearrangement of line control flow in response to different contingencies. The TCSC additionally can manage consistent state control flow within its rating limits.

From a principal innovation point of view, the TCSC resembles the customary series capacitor. All the power hardware is situated on a confined steel stage, including the Thyristor valve that is utilized to control the conduct of the main capacitor bank. In like manner the control and insurance is situated on ground potential together with other assistant frameworks. Figure demonstrates the principle setup of a TCSC and its operational outline. The firing edge and the warm furthest reaches of the Thyristors determine the boundaries of the operational graph.



OPERATING PRINCIPLE OF UPFC

The fundamental segments of the UPFC are two voltage source inverters (VSIs) sharing a typical dc stockpiling capacitor, and associated with the power framework through coupling transformers. One VSI is associated with in shunt to the transmission framework by means of a shunt transformer, while the other one is associated in series through a series transformer.

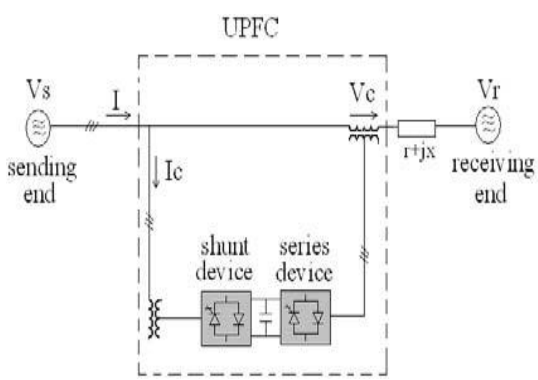


Figure 1: UPFC functional scheme

The series inverter is controlled to inject a symmetrical three stage voltage framework (Vse), of controllable size and stage point in series with the line to control dynamic and receptive power flows on the transmission line. Along these lines, this inverter will trade dynamic and responsive power with the line. The responsive power is electronically given by the series inverter, and the dynamic power is transmitted to the dc terminals. The shunt inverter is worked so as to request this dc terminal power (positive or negative) from the line keeping the voltage over the capacity capacitor Vdc steady. In this way, the net genuine power consumed from the line by the UPFC is equivalent just to the losses of the inverters and their transformers. The remaining limit of the shunt inverter can be utilized to trade responsive power with the line so to give a voltage direction at the association point.

The two VSI's can work independently of each other by separating the dc side. So all things considered, the shunt inverter is operating as a STATCOM that generates or ingests responsive energy to manage the voltage extent at the association point. Instead, the series inverter is operating as SSSC that generates or ingests responsive energy to control the present flow, and hence the power low on the transmission line. The UPFC has numerous conceivable operating modes. Specifically, the shunt inverter is operating in such an approach to inject a controllable current, ish into the transmission line. The shunt inverter can be controlled in two unique modes:

VAR Control Mode: The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and alters gating of the inverter to establish the desired current. For this method of control a criticism flag representing the dc transport voltage, Vdc, is additionally required. Programmed Voltage Control Mode: The shunt inverter receptive current is consequently managed to maintain the transmission line voltage at the point of association with a reference esteem. For this method of control, voltage criticism signals are obtained from the sending end transport feeding the shunt coupling transformer.

The series inverter controls the extent and angle of the voltage injected in series with the line to influence the power flow on hold. The genuine estimation of the injected voltage can be obtained in a few ways. Coordinate Voltage Injection Mode: The reference inputs are specifically the greatness and phase angle of the series voltage. Phase Angle Shifter Emulation mode: The reference input is phase removal between the sending end voltage and the receiving end voltage. Line Impedance Emulation mode: The reference input is an impedance incentive to insert in series with the line impedance Automatic Power Flow Control Mode: The reference inputs are values of P and Q to maintain on the transmission line despite framework changes.

ELECTRIC SPRING (ES) CONCEPT

Voltage control in LV and MV dispersion systems and request side administration (DSM) have customarily beentreated and handled independently. Voltage control is normally accomplished by control devices examined in the past area. DSM, then again, is utilized in a more circulated manner (frequently at the appliance level) and is predicated on intelligence or correspondence office in the appliance [10]–[12].

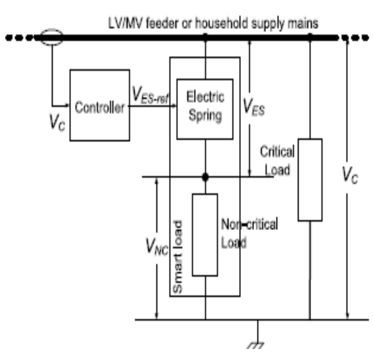


Figure 2: Electric spring set-up for smart loads.

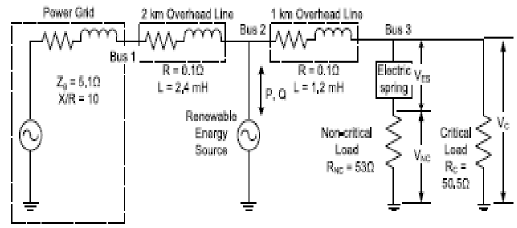


Figure 3: Simulation set-up with an intermittent source and an equivalent power grid.

On the other hand, an integrated way to deal with voltage control and amassed request activity could be accomplished by separating the loads into basic (C) loads requiring consistent voltage and uninterrupted supply and NC, impedance-type loads. At times of era deficiency or system constraint, the voltage of the NC loads is decreased while regulating the voltages over the C loads. This addresses the era shortage or system constraint and furthermore facilitates better voltage direction of the C loads through control of the supply impedance voltage drop.

One approach to practice this control is to utilize the supposed ESs which are control electronic compensators that inject a voltage with controllable extent VES in series with every NC load to direct the voltage VC over the C stack as appeared in Fig. 1.The voltage VNC over the NC loads is accordingly controlled (with in allowable limits) and the dynamic power devoured by them modulated. The series combination of the ES and the NC load thus goes about as a brilliant load which ensures firmly managed voltage across the C stack while allowing its own energy utilization to vary and in this manner, take an interest sought after side response. Adding the voltage VES in quadrature with the present flowing through the ES ensures trade of responsive power just like conventional voltage compensators including STATCOM. For further details

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about ESs the perusers can allude to [2] and [5].

ES VERSUS STATCOM

A. Test System

With a specific end goal to think about the voltage direction performance of a single ES against that of a STATCOM, a basic test system as appeared in Fig. 2 has been considered. It comprises of a power source acting as the main power network and a separate controllable power source to copy an intermittent inexhaustible

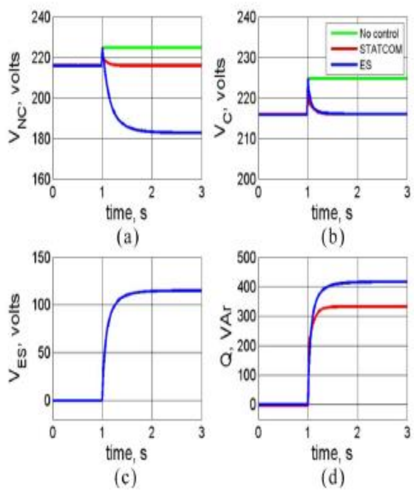

Fig. 4. System response following abatement in receptive power consumption of the intermittent source from 467 to 110 VAr. (a) Non-basic load voltage.(b)Critical stack voltage. (c)Electric spring voltage. (d)Reactive power exchange.

The controllable source is fit for injecting variable dynamic or potentially receptive power which causes the voltage a cross the C load to change. For effortlessness both C and NC loads are represented by resistors in spite of the fact that they don't have to be necessarily resistive. The parameters utilized for the system and the ES are the same as in [2] and are not rehashed here because of space restriction. The above framework is modeled in MATLAB/SIMULINK using a controllable voltage source representation for both ES and STATCOM. Modeling and control of ES is discussed in [13]. The greatness of the controllable voltage representing the ES is controlled using a PI controller to minimize the difference between the genuine and reference values of the voltage across the C stack. Phase angle of the voltage source is locked in quadrature to the phase angle of series current to ensure there is no dynamic power exchange. The STATCOM is modeled by a controllable voltage source in series with impedance. Its control circuit is fundamentally the same as that of ES with the exception of the adjustments because of its parallel association with the C and NC load.

B. Voltage Suppress Mode

The voltage over the loads is increased over the nominal value (216 V) by reducing the receptive power assimilation of the inexhaustible source. This is to test the capacity of an ES and a STATCOM to suppress the voltage and control it at the nominal esteem. At t = 1.0 s, the responsive power absorption by the intermittent sustainable source is lessened from 467 VAr down to 110 VAr. Without any voltage control, the heap voltage increases from the nominal estimation of 216 V up to 224 V as shown by Fig. 4(a) and (b). Both STATCOM and ES are capable torestore the voltage over the C stack back to the nominal value as appeared by the overlapping blue and red traces in Fig. 4(b).The ES achieves this by injecting around 115 V in series with the NC stack the voltage crosswise over which drops to around 185 Vas appeared by the blue traces in Fig. 4(a) and (c). Keeping in mind the end goal to suppress the voltage, both ES and STATCOM retain responsive

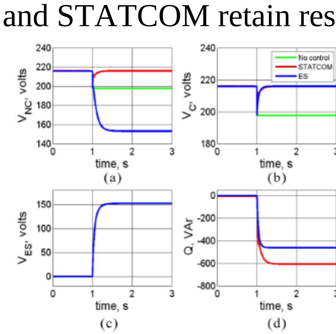

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Fig. 5.System response following increase in receptive power consumption of the intermittent source from 467 to 1100 VAr. (a) Noncritical load voltage.(b)Critical stack voltage. (c)Electric spring voltage. (d)Reactive power exchange.

It is watched that the responsive power devoured by ES to restore the C stack voltage to typical esteem is higher than the receptive power devoured by STATCOM to accomplish a similar voltage. This can be explained from Fig. 1. An increase in ES voltage will result in an abatement in NC stack voltage. This causes a decline in the dynamic power utilization of the (resistive) NC stack. To have a higher general dynamic/receptive power utilization for the brilliant load, ES needs to devour more responsive power. Note that the X/R proportion is not extensive (around 2) for this situation which is the reason both dynamic and responsive power influence the voltage control.

C. Voltage Support Mode

To investigate the opposite effect of what was described in the previous subsection, the voltage across the loads is reduced by increasing the reactive power absorption of the renewable source. This is to test the ability of an ES and a STATCOM to support the voltage and regulate it at the nominal value. At t = 1.0 s, the reactive power absorption by the intermittent renewable source is increased from 467 to 1100 VAr. Without any voltage control, the load voltage is seen to drop from the nominal value of216 V to slightly below 190 V as shown by the green trace in Fig. 5(a) and (b).

As before, both STATCOM and ES are able to restore the voltage across the C load back to the nominal value as shown by the overlapping blue and red traces in Fig. 5(b). The ES achieves this by injecting about 150 V in series with the NC load the voltage across which drops to about 150 V as shown by the blue traces in Fig. 5(a) and (c). In order to suppress the voltage, both ES and STATCOM inject reactive power (as indicated by negative sign of Q) into the system as shown in Fig. 5(d) with ES requiring to inject about 150 VAr less

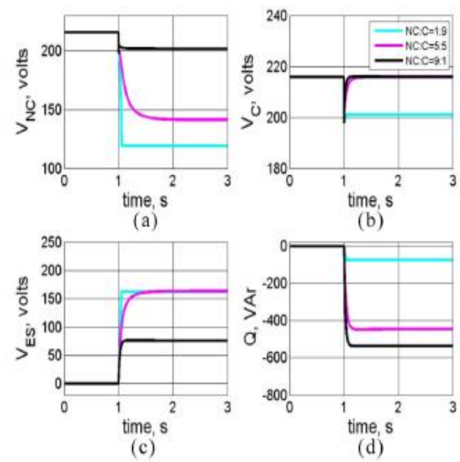

Fig. 6. System response for different distribution of noncritical and critical loads (NC:C). Disturbance is increase in reactive power consumption of the intermittent source from 467to1100VAr. (a)Noncritical load voltage. (b)Critical load voltage. (c) Electric spring voltage. (d) Reactive power exchange.

This is due to the fact that an increase in ES voltage will result in a reduction of NC load voltage which causes a decrease in active power consumption of the(resistive) NC load. Hence, the ES needs to produce less reactive power than an equivalent STATCOM to restore the system voltage due to the similar arguments about the X/R ratio as mentioned earlier for the voltage suppress case.

D. Proportion of C and NC Loads

An ES injects a voltage is series with the NC stack in order to manage the voltage over the C stack. The extent of the C and NC stack is subsequently, very vital toward the effectiveness of an ES both as far as its voltage regulation capability and

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furthermore the amount of responsive power (and hence its rating) exchanged with the framework. The receptive capability of an ES is administered by the result of the voltage it injects and the present flowing through it (which is the same as the current through the NC stack). In the event that the injected voltage increases, the voltage over the NC stack and hence the current reduces which limits the responsive capacity of an ES and along these lines its capacity to direct the voltage over the C stack. For low extent of NC stack, the devotion of current is restricted which constrains the capacity of an ES thought about to the situation when the extent of NC stack is moderately high. To confirm this, reproductions have been directed with different proportions of NC and C loads.

It can be seen that for high extent of NC load(NC:C = 9:1) appeared by the dark traces, the C stack voltage is restored back to its nominal esteem, with just 80 V injected by the ES. This results in little change (from 216 to 202 V) in voltage over the NC stack. Voltage regulation is comparable for square with extent of C and NC (NC:C = 5:5)loads appeared by red traces. Be that as it may, the voltage across the NC stack is lower (around 140 V) than before due to larger injected voltage (160 V) by the ES. In view of open statistics in Hong Kong [14], around half of loads, (for example, heaters,

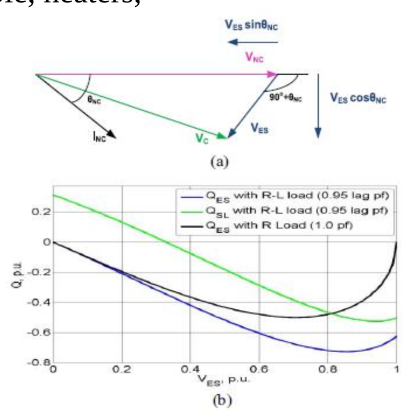

Fig. 7. (a) Phasor diagram showing relationship between voltages across noncritical load, critical load, and ES. (b) Variation of reactive power of ES and smart load with respect to ES voltage for R–L and R noncritical loads.

For low proportion of NC load (NC:C = 1:9), it is not possible to restore the voltage across the C load back to its nominal value as shown by the cyan trace in Fig. 5(b). This is because of the low fidelity in current which restricts the reactive capability of the ES to less than 100 VAr [Fig. 5(d)] for a maximum possible ES voltage of 160 V. This demonstrates that the voltage regulation capability of an ES is dependent on the relative proportion of NC and C load. Lesser the proportion of NC load, lower is the voltage regulation capability of an ES. As the second generation of ES with embedded energy storage [15] has emerged, there would be more flexibility in control which would be demonstrated in a future paper.

The reactive power exchange with the ES depends on the injected voltage V_{ES} and also on the impedance of the NC load. Consider the circuit shown in Fig.3. For a resistive–inductive(R–L) type NC load with impedance $Z_{NC}\angle\theta_{NC}$, the voltages V_C, V_{ES}, and V_{NC} are shown on the phasor diagram in Fig. 7(a)when the ES is working in voltage support (i.e., capacitive)mode. From the phasor diagram, we can write

$$V_C^2 = (V_{NC} - V_{ES}\sin\theta_{NC})^2 + (V_{ES}\cos\theta_{NC})^2 \quad (1)$$

$$V_{NC} = \pm\sqrt{V_C^2 - (V_{ES}\cos\theta_{NC})^2} + V_{ES}\sin\theta_{NC} \quad (2)$$

$$Q_{ES} = V_{ES}I_{NC}\sin(-90^0) = -V_{ES}I_{NC} = -\frac{V_{ES}V_{NC}}{Z_{NC}} \quad (3)$$

$$Q_{NC} = V_{NC}I_{NC}\sin\theta_{NC} = \frac{V_{NC}^2}{Z_{NC}}\sin\theta_{NC}. \quad (4)$$

Here, QES and QNC are the reactive powers of the ES and the NC load, respectively. For

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a purely resistive NC load, the reactive power of the ES and the smart load will be equal. However, they would be different if the NC is not purely resistive. If the ES is working in voltage support(i.e., capacitive) mode with a NC load of R–L type, the total reactive power of the smart load QSL is given by

$$Q_{SL} = Q_{ES} + Q_{NC} \tag{5}$$

$$Q_{SL} = \frac{-V_{ES}\left(\pm\sqrt{V_C^2 - (V_{ES}\cos\theta_{NC})^2} + V_{ES}\sin\theta_{NC}\right)}{Z_{NC}} + \frac{\left(\pm\sqrt{V_C^2 - (V_{ES}\cos\theta_{NC})^2} + V_{ES}\sin\theta_{NC}\right)^2}{Z_{NC}} \sin\theta_{NC}. \tag{6}$$

Similarly, for the ES in voltage suppress (i.e., inductive)mode, we can write

$$V_{NC} = \pm\sqrt{V_C^2 - (V_{ES}\cos\theta_{NC})^2} - V_{ES}\sin\theta_{NC} \tag{7}$$

and

$$Q_{SL} = \frac{V_{ES}\left(\pm\sqrt{V_C^2 - (V_{ES}\cos\theta_{NC})^2} - V_{ES}\sin\theta_{NC}\right)}{Z_{NC}} + \frac{\left(\pm\sqrt{V_C^2 - (V_{ES}\cos\theta_{NC})^2} - V_{ES}\sin\theta_{NC}\right)^2}{Z_{NC}} \sin\theta_{NC}. \tag{8}$$

From (3), (6), and (8) it is clear that the reactive power of the ES and the smart load are both dependent on NC load impedance (Z_{NC}). A decrease in the value of Z_{NC} (increase in the NC load) will result in an increase in reactive power. Hence, a higher proportion of NC load will increase the effectiveness of an ES.

DISTRIBUTION NETWORK IN SHA LO WAN BAY, LANTAU ISLAND, HONG KONG

A. Test Network

Another contextual analysis has been performed on a piece of the distribution organize at Sha Lo Wan Bay in Lantau Island of Hong Kong. The goal is to think about the voltage regulation performance of a gathering of ESs against a STATCOM. The11 kV substations and a piece of the 220 V feeder arrange as shown in Fig. 13 is considered for this paper.

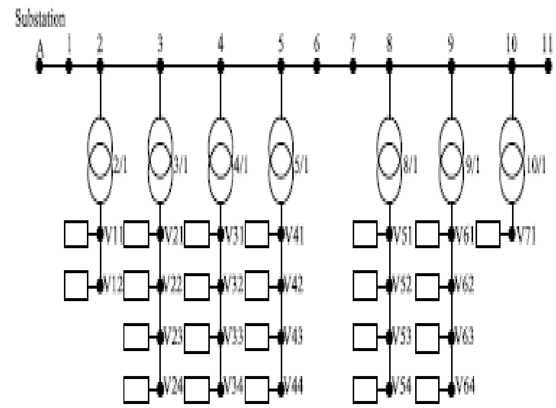

Fig. 8.Single line diagram of a part of the distribution network from ShaLo Wan Bay, Lantau Island, Hong Kong.

The network data are provided in the Appendix. The parameters of the distribution lines are practical values, but the loads are arbitrarily set because the actual load data are confidential due to privacy policy. There are 23 purely resistive loads connected to the 220 V network. Each load has a rating of 30 kW which is assumed to have a 50:50 split between C and NC load. An ES is connected in series with each of the 23 NC loads.

B. Voltage Support Mode

To validate the collective performance of the ESs and compare it with the voltage control of a STATCOM, a 5% stepreduction in the 11 kV substation (substation A) voltage has been simulated. Voltages at all the load connection points across the distribution network at Sha Lo Wan Bay (show in Fig.8) are monitored.

The three subplots in Fig.9 correspond to the cases with no voltage compensation, with a STATCOM regulating the voltage at the 11 kV substation (substation A) and ESs connected in series with all the NC loads at

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220 V level. The distribution of voltage is shown in Fig. 9 along the 11 kV feeder (x-axis)and also along each of the 220 V feeders (y-axis). With out any voltage compensation [Fig.9(a)] the voltage regulation is poor (>5%) getting worse as we move further away along the 11 kV feeder and also the 220 V feeders due to natural voltage drop in the lines.

The STATCOM regulates the voltage at substation A which results in very good regulation at bus 1 [Fig.9(b)]. However, the voltage regulation is poorer (but much better than the case without voltage compensation) further away along the 11 kV and 220 V feeders.

In the case with ESs, the voltage regulation turns out to be better, especially at the loads which are at the far ends of the 220 V feeder. As the ES regulates the voltage by manipulating the voltage drop across the supply impedance, larger impedance (for distant loads) improves the effectiveness of ESs which is apparent from Fig.9(c).

The distribution of the voltage across all the load buses of Sha Lo Wan Bay distribution system is captured in terms of their mean and standard deviation in Fig. 9 for voltage support and voltage suppress modes (discussed in the next subsection).For voltage support mode, the distributed ESs provide much better (lower average) and tighter (lower standard deviation)voltage regulation than a STATCOM [Fig.9(a)].

This is further substantiated by the total voltage regulation shown in Fig.11(b) which shows ESs achieve three times better total regulation than a STATCOM.

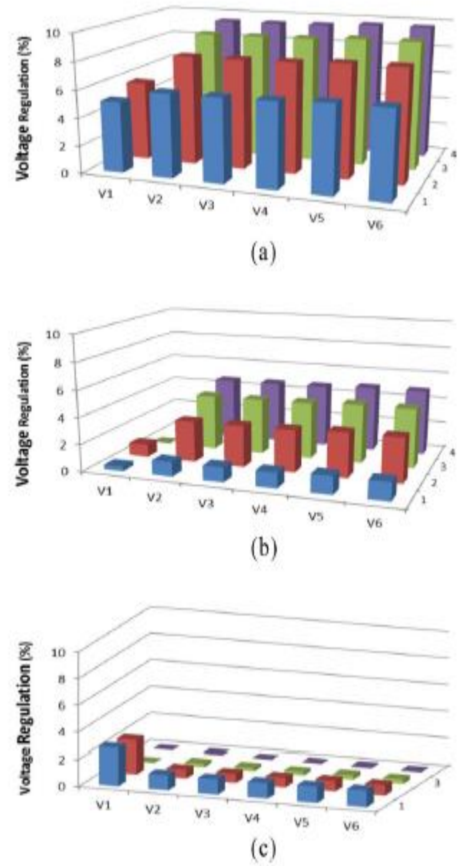

Fig. 9.Voltage regulation with distributed ESs and STATCOM following5% reduction in source voltage at substation A. (a) No compensation device.(b) STATCOM. (c) ESs.

C. Voltage Suppress Mode

Comparative exercise as above has been led to look at the aggregate performance of the ESs and a STATCOM under voltage suppress mode. A 5% stage increase in the 11 kV substation voltage has been recreated. The voltage control performance is appeared in Fig. 10(b) as far as the mean and standard deviation of the voltages at all the heap busses. It can be seen that voltage control without any voltage compensation is within the satisfactory (5%) limits. In this case, the voltage direction really improves far from the 11 kV bus (substation A) because of the normal voltage drop over the 11 kV and 220

V feeders. Like the voltage bolster mode, ESs give much better (lower normal) and more tightly (lower standard deviation) voltage direction than a STATCOM. The aggregate voltage control appeared in Fig. 11(b) delineates that the gathering of ESs achieves around two times preferable aggregate direction over a STATCOM. The aggregate responsive power capacity required for the gathering of ESs [Fig. 11(a)] is around 30 times less than that of the STATCOM. The above contextual investigation on the Sha Lo Wan Bay dissemination arrange in Hong Kong demonstrates the effectiveness of appropriated voltage control through a gathering of ESs under both voltage bolster and suppresses modes. A gathering of disseminated ESs achieves much better aggregate voltage direction contrasted with a STATCOM with substantially less responsive ability.

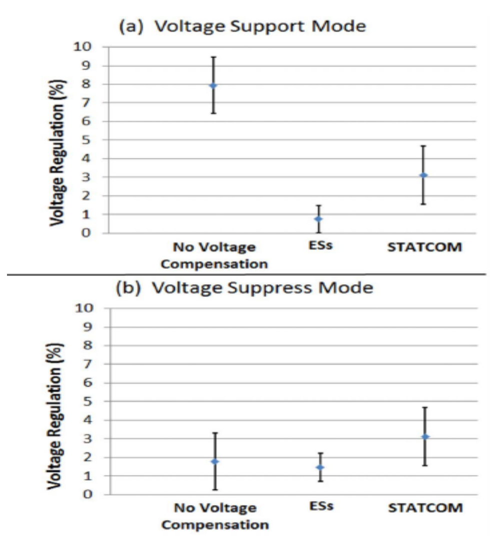

Fig. 10.Voltage distribution at different parts of the Sha Lo Wan distribution network under.

(a) Voltage support. (b) Voltage suppress modes.

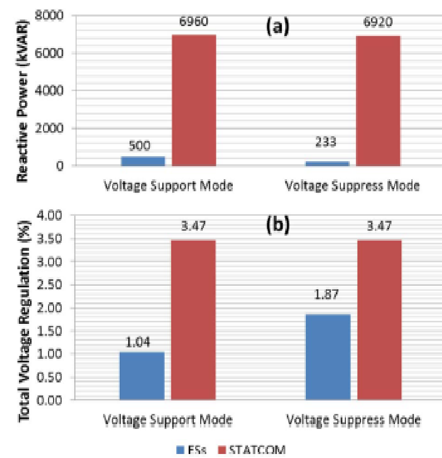

Fig. 11. (a) Reactive power required. (b) Total voltage regulation achieved collectively by all the distributed ESs and the STATCOM under voltage support and suppress condition.

SIMULATION MODELS AND RESULTS

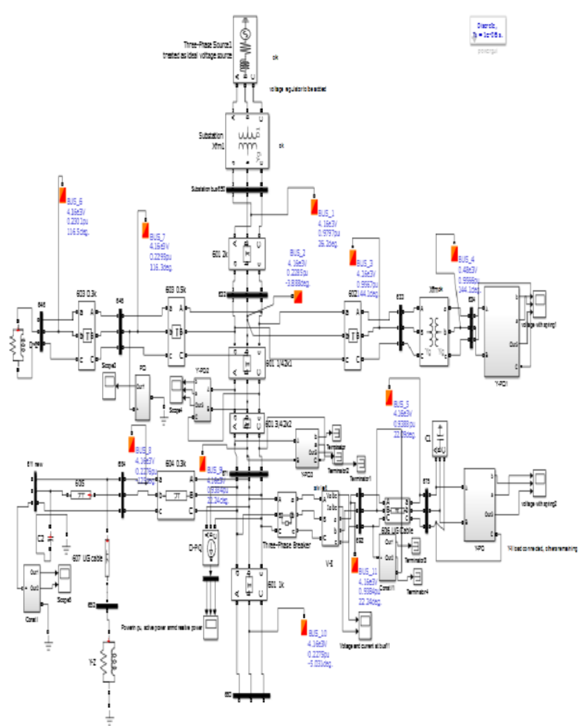

Figure 12: IEEE 13-node test feeder network with distributed representation

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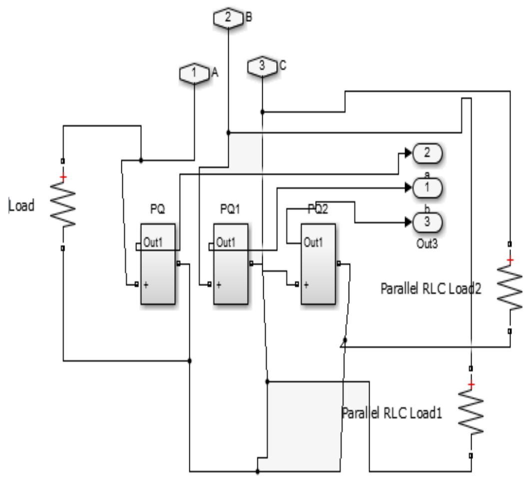

Operational simulink diagram of Electric spring wave form for voltage regulation

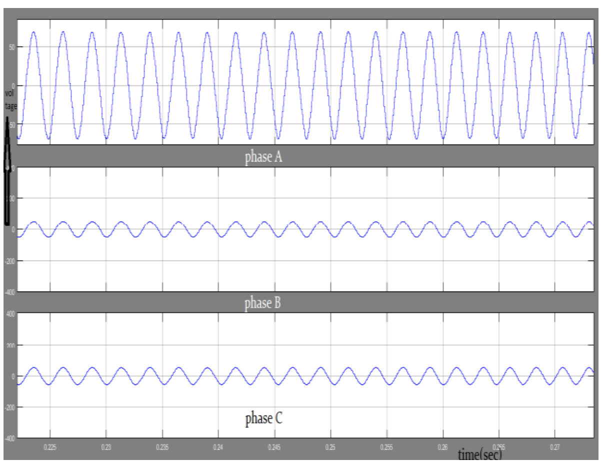

Figure 13: Voltage variations at spring1

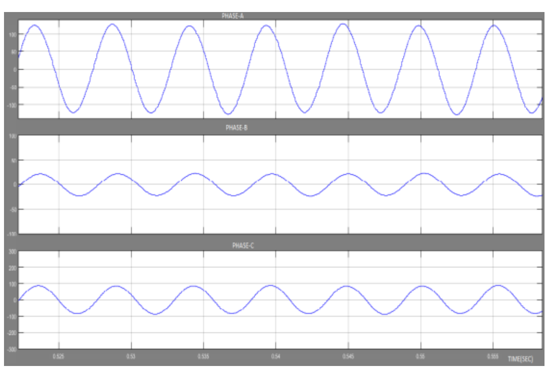

Figure 14: Voltage variations at spring2

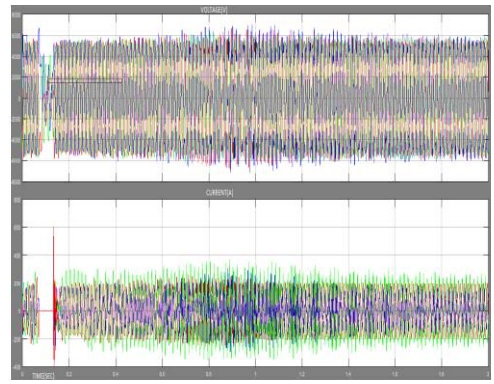

Figure 15: Voltage and current at BUS-1

CONCLUSION

In this paper, a correlation is made between circulated voltage control using ES against the customary single point control with STATCOM. For a given scope of supply voltage variety, the aggregate voltage direction, and the aggregate receptive limit required for every choice to deliver the desired voltage control at the point of association are analyzed. A straightforward contextual analysis with a single ES and STATCOM is presented first to demonstrate that the ES and STATCOM require practically identical responsive energy to accomplish comparable voltage direction. Examination between a STATCOM and ES is additionally substantiated through comparable contextual analyses on the IEEE 13-transport test feeder framework and furthermore on a piece of the conveyance arrange in Sha Lo WanBay, Hong Kong. In the two cases, things being what they are a gathering of appropriated ESs requires less general receptive power limit than STATCOM and yields better aggregate voltage control. This makes ESs a promising innovation for future shrewd lattices where particular voltage direction for touchy loads would be necessary close by request side response.

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