Improved steady state and transient stability analysis using super capacitor and STATCOM for a multi-machine power system integrated with hybrid renewable energy

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ABSTRACT

This article will explain how to utilize a static synchronous compensator (STATCOM) near a wind farm to restore organization voltage following framework side disturbances, for example, a line-line fault, temporary outage of a wind turbine, and unexpected load shifts. This study describes security enhancement using wind and solar cell for a multi-machine power system with integration of super capacitor (SC) and STATCOM. For SC's bidirectional DC/DC converter to be overhauled, a corresponding required regulator (PID)-important damping controller (PID-SDC) is expected. Damping properties of low-recurrence movements associated among studied multimachine power system viability of suggested SC in conjunction among PID-SDC in chipping away at presentation of investigated structure under various disruptive effect circumstances is further demonstrated utilizing time-space reproduction.

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1. INTRODUCTION

Because of inherent irregularity and difference of renewable energy sources (RESs), integration of STATCOM with super capacitor (SC) and energy storage devices like battery and others persist linked together in various crossover designs to enhance power supply dependability. Many RESs utilise it for power backup to create energy on board or to smooth power changes [1]-[4]. Wind and photovoltaic (PV) persist most often used RESs for combining in strategic cross-breed control. The battery bank was used in construction to give brief ability to stack vagabonds, and force pioneers structure was likewise introduced to work among power streams among explicit energy sources [4]. There persist a couple of components that sway power system trickiness of structure, one of a conclusive explanation is decreases of responsive power hold and voltage lop-sidedness. An economical mode of providing power backup with capacitor and integrating with STATCOM improves stability. Notwithstanding, they can't give smooth control of responsive power made. Ruth is as of now used for controlling open power as they have an ideal control framework over for most part used capacitors. In this work, one of flexible AC transmission system (FACTS) contraptions, STATCOM is taken, as it can give open power compensation [5]-[9]. To fathom lead of judicious power structure, an IEEE-16 vehicle system fused among seaside breeze PV hybrid farm has been considered in this work. Here seaside breeze farm relies upon permanent magnet synchronous generator (PMSG). Among compromise of seaside breeze PV crossbreed farm among power structure; numerous troubles like voltage strength, transient sufficiency, huge power changes, etc come into place.

2. SYSTEM CONFIGURATION AND MODEL

Figure 1 depicts concept of a multimachine power framework associated among a crossover wind PV farm via suggested SC-based energy-hoarding unit. PV-developed wind turbine generator (WTG) and PV show persist freely integrated among a standard DC interface via a DC/DC and a voltage-source converters. In this model a 30kilometre association network along with voltage-source inverter and two transformers of push forward type are connected to a standard DC interface to one vehicle of multimachine power framework [10-12].

The combination of DC/DC converter with PV shows that the DC power accomplice has been improved to a greater maximum power point tracking (MPPT) which makes to work as PV social affair's MPPT controller. Integration of two gadgets is done to realise a DC/DC converter which is bidirectional since DC accomplice's powers from equivalent added WTG and PV pack differ contingent upon wind speed and light-based irradiance [13-16]. Coordinated multimachine power design is portrayed in Figure 1. 1 is a 12-transport nonexclusive power structure among four huge simultaneous generators (SGs), loads, and a 230 kV related transmission association.

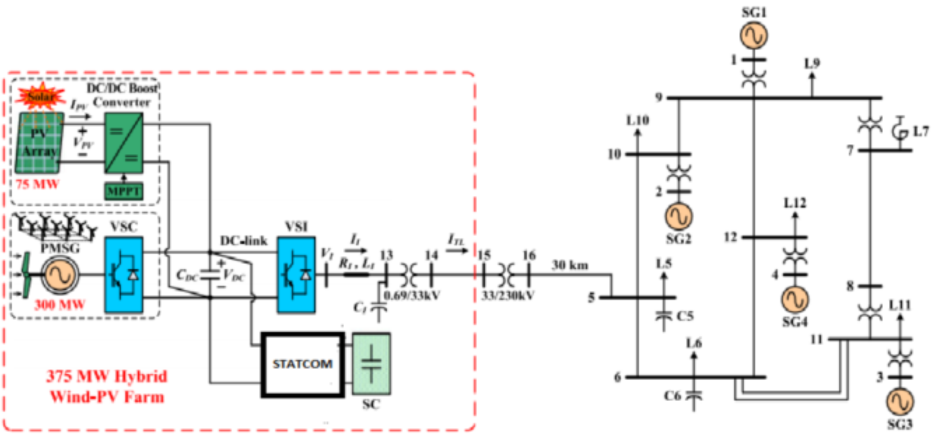

Figure 1. Block diagram of 12 bus power system

3. MODELLING OF PV MODULE

A PV module, basically relies on the principal of PV effect which converts the energy radiated by the sun into electrical energy.

3.1. PV module characteristics

A PV module is similar in operation to normal junction photo detectors. In this hole-electrons pairs are created when PV energy falls on the surface without any reverse bias. The single line diagram of PV module is shown in Figure 2.

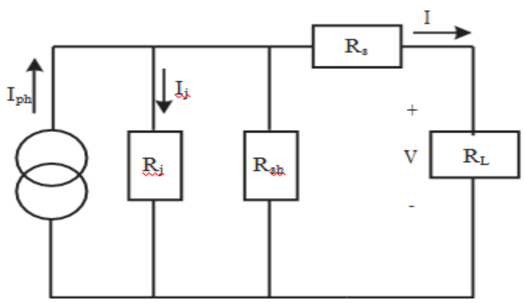

Figure 2. PV module (single line diagram)

In the above figure I_{ph} is answerable for cell PV current, R_j is liable for nonlinear check of p-n crossing point, and R_{sh} & R_s persist liable for customary shunt and series protections, separately. Commonly, the value of R_{sh} is high, while the value of R_s is to some degree unobtrusive. Accordingly, two of them might be eliminated to upgrade assessment. They persist when connected in a series-comparable blend to shape PV bundles. Condition watches out for numerical model used to work on PV show:

$$I = n_p I_{ph} - n_p I_{rs}\left[e^{\left(\frac{q}{kTA}*\frac{V}{n_s}\right)} - 1\right]$$

where I denotes PV yield current, V denotes yield voltage, n_s denotes number of series cells, n_p denotes number of similar cells, q denotes electron charge, k denotes Boltzman constant, T is temperature, and I_{rs} is revise dousing current. A is the p-n assembly ideality factor. Factor a selects the sun coordinated cell's deviation from the best p-n assembly credits in order to coordinate the sun-controlled cells from the best p-n crossing point character. It has a value range of one to five. Current photograph I_{ph} is affected by solar irradiance and cell temperature, as seen below.

$$I_{ph} = [I_{scr} + K_i(T - T_r)]\frac{S}{100}$$

I_{scr} stands for solar cell hamper and radiation at room temperature, K_i for short out current temperature coefficient, and S for solar irradiance in mW/cm^2. A Simulink model of a PV cluster is shown in the figure. There are three sub-systems in the model. One sub-system to imitate a PV module and two more sub-systems to imitate I_{ph} and I_{rs}.

3.2. Modelling of PMSG and wind turbine

The mechanical energy developed by wind turbine is given by the equation:

$$P_{mw} = 0.5\rho_a \pi R_t^2 V_w^3 C_{pw}(\lambda_w, \beta_w) \tag{1}$$

where ρ_a denotes air thickness (kg/m3), R_t length of turbine cutting edge (m), V_ω breeze speed (m/s), $C_{p\omega}$ (w, w) force coefficient of wind turbine, which is an element of tip speed proportion $_W$=R_t/V_ω, and edge pitch point ω (degree), is shown below.

$$C_{pw}(\lambda_w, \beta_w) = c_1[c_2/\Gamma - c_3\beta_w - c_4(\beta_w)^c{}_5 - c_6]\cdot \exp(-c_7/\Gamma) \tag{2}$$

$$1/\Gamma = 1/(\lambda_w + c_8\beta_w) - c_9/[(\beta_w)^3 + 1] \tag{3}$$

$$(L_{dPG}/\omega_b)p(i_{dPG}) = -R_{PG}i_{dPG} + \omega_{PG}L_{qPG}i_{qPG} - v_{dPG} \tag{4}$$

$$(L_{qPG}/\omega_b)p(i_{qPG}) = -R_{PG}i_{qPG} - \omega_{PG}L_{dPG}i_{dPG} - v_{qPG} + \omega_{PG}\psi_{PM} \tag{5}$$

4. STATIC SYNCHRONOUS COMPENSATOR

Static synchronous compensator statcom (STATCOM) be set up toward do high one about a kind execution and its compensation doesn't depend upon ordinary coupling voltage. Inside thusly, STATCOM be uncommonly convincing during power structure agitating impacts. Inside expansion, much research avows a couple about ideal conditions about STATCOM. These inclinations appeared differently within relation toward other shunt compensators include:
- Size, weight, and cost decline
- Equality about loosen and driving yield
- Precise and steady open power manage within speedy response
- Possible unique consonant channel limit

STATCOM could be a controlled responsive force supply. It gives predetermined responsive force age and retention completely by implies that of electronic interaction of voltage and current waveforms in a voltage source converter (VSC). A STATCOM rule graph is displayed in Figure 3. VSC as shown in Figure 4 is associated among a utility transport through shunt electrical gadget. Get-away is that transport voltage. Iac is STATCOM infused current as shown in Figure 5. Vout is that VSC yield voltage. V_{dc} and I_{dc} square measure

DC electrical gadget viewpoint voltage and flow. An insulated-gate bipolar transistor (IGBT) among consecutive diode means three arm IGBT bridge. Top three IGBTs region unit alluded to as certain bunch and base three IGBTs region unit alluded to as regrettable group IGBTs. Electrical converter activity happens, when IGBTs lead and convertor activity happens, once diodes direct.

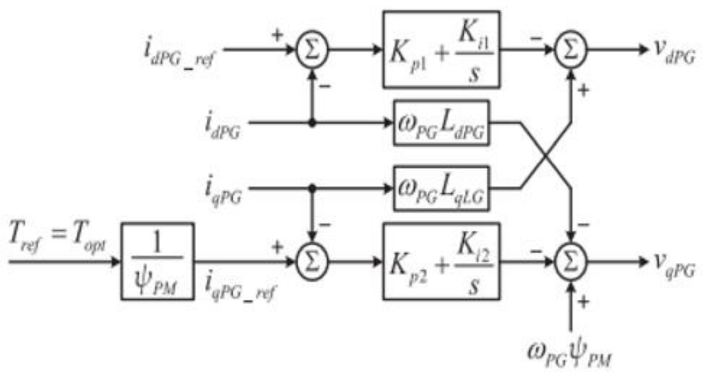

Figure 3. Control diagram of PMSG VSC

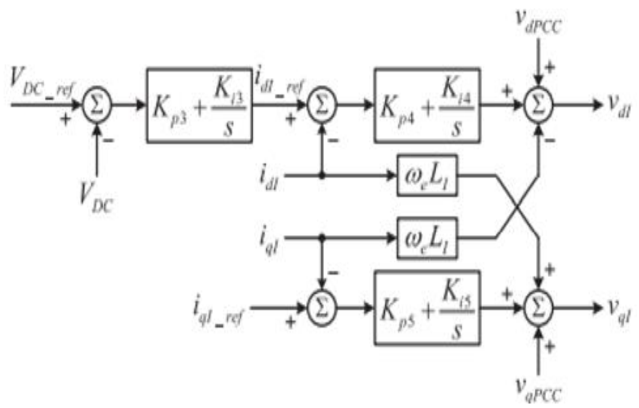

Figure 4. Control diagram of voltage source inverter (VSI)

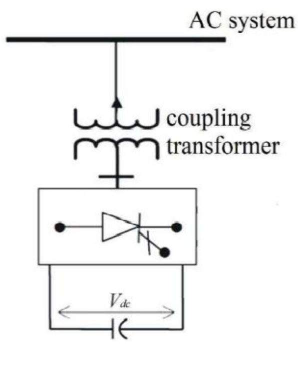

Figure 5. STATCOM operation within a power system

5. SIMULATION RESULTS

Case 1: minimization of fluctuations in power by the proposed SC and STATCOM's effectiveness (in Appendix)

In this study, the effect of SC on power fluctuation minimization integrated to a framework of multi-machine power system as shown in Figure 6 is tested for different wind speeds and solar irradiance. The parameters in this research are shown in Table 1.

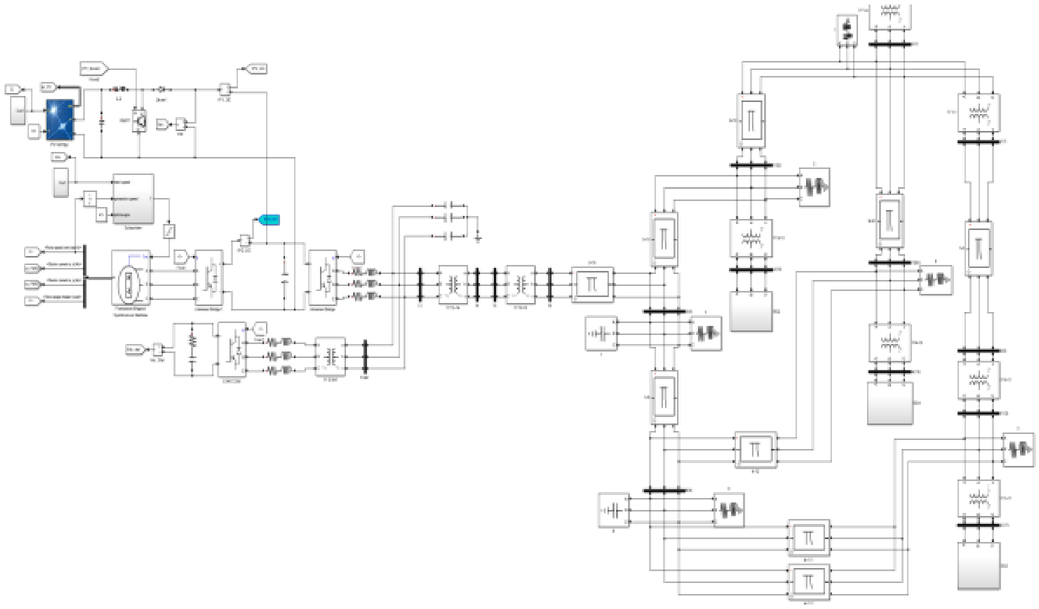

Figure 6. Simulink model of proposed system

Case 2: transient steady analysis of the system by integrated model (SC and STATCOM) (in Appendix: Figures 7 and 8)

Table 1. System parameters

Single PMSG-based WT of the studied 375-MW hybrid wind-PV farm				
$P = 2$ MW, $V = 690$ V, $R_{PG} = 0.042$, $L_{dPG} = 1.05$, $L_{qPG} = 0.75$, $\psi_{PM} = 1.16$ $H_t = 2.5$ s, $H_g = 0.5$ s, $K_{sh} = 0.3$ pu/elec · rad, $D_{sh} = 0.05$ pu·s/elec · rad, $c_1 = 0.5, c_2 = 116, c_3 = 0.4, c_4 = 0, c_5 = 0, c_6 = 5, c_7 = 21, c_8 = 0.08, c_9 = 0.035$				
Single PV array and dc/dc boost converter of the studied 375-MW hybrid wind-PV farm				
1) PV module (SUNPOWER SPR-305E-WHT-D): $P_{mp} = 305.2$ W, $V_{mp} = 54.7$ V, $I_{mp} = 5.58$ A, $N_s = 96$ cells $V_{oc,n} = 64.2$ V, $I_{sc,n} = 5.96$ A, $R_s = 0.037998\ \Omega$, $R_p = 993.51\ \Omega$ 2) PV array: $N_{ms} = 11$, $N_{mp} = 150$, $R_{sa} = (N_{ms}/N_{mp}) \times R_s$, $R_{pa} = (N_{ms}/N_{mp}) \times R_p$ 3) dc/dc boost converter: $C_{PV} = 500\ \mu$F, $R_P = 0.001\ \Omega$, $L_P = 1.0$ mH				
Common dc link: $V_{DC} = 1200$ V, $C_{DC} = 0.12$ F				
Single SC and bidirectional dc/dc converter				
1) SC model: $C_{SC} = 90$ F, $R_{sSC} = 0.010\ \Omega$, $R_{pSC} = 1.04 \times 10^4\ \Omega$ 2) Bidirectional dc/dc converter: $R_S = 0.02$ mΩ, $L_S = 20\ \mu$H				
Controllers				
$K_{p1} = 2.692$, $K_{i1} = 42$ s^{-1}, $K_{p2} = 1.989$, $K_{i2} = 42$ s^{-1}, $K_{p3} = 0.917$ $K_{i3} = 157.7$ s^{-1}, $K_{p4} = K_{p5} = 0.651$, $K_{i4} = K_{i5} = 5.425$ s^{-1}, $K_{p6} = 1.309$, $K_{i6} = 0.016$ s^{-1}, $K_{p7} = 0.0003$ $K_{i7} = 0.0028$ s^{-1}, $T_1 = 50$ s, $T_2 = 25$ s				
Generator	SG1	SG2	SG3	SG4
Rated MVA	750	640	384	474
Rated kV	15.5	15.0	18.0	13.8
Power factor (lagging)	0.85	0.85	0.85	0.9
X_d (p.u.)	1.22	1.70	1.651	0.92
X'_d (p.u.)	0.174	0.245	0.232	0.3
X_q (p.u.)	1.16	1.64	1.59	0.51
X'_q (p.u.)	0.25	0.38	0.38	0.51
T'_{do} (s)	8.97	5.9	5.9	5.2
T'_{qo} (s)	0.50	0.54	0.535	0.50
H (s)	4.768	3.963	3.302	3.177

6. CONCLUSION

The reenactment discoveries likewise show that SC can stifle power variances and work on presentation of explored framework when breeze speed and sun-oriented illumination change. Series remuneration has been utilized to smoothen force vacillations principally caused because of variety of wind speed and sun powered illumination. Time space recreation exposed to a three-stage flaw and line to ground issue is performed at a different area to approve viability of STATCOM associated at point of common coupling (PCC). It tends to be closed from reenacted result that IEEE 12 transport incorporated among huge scope cross breed wind-PV ranch can be made more minimal and stable among utilization of STATCOM. It is seen that force changes persist damped and settling time has diminished among utilization of STACOM. It can likewise be inferred that STATCOM can repay receptive power and further develop voltage solidness for duration of time space.

APPENDIX

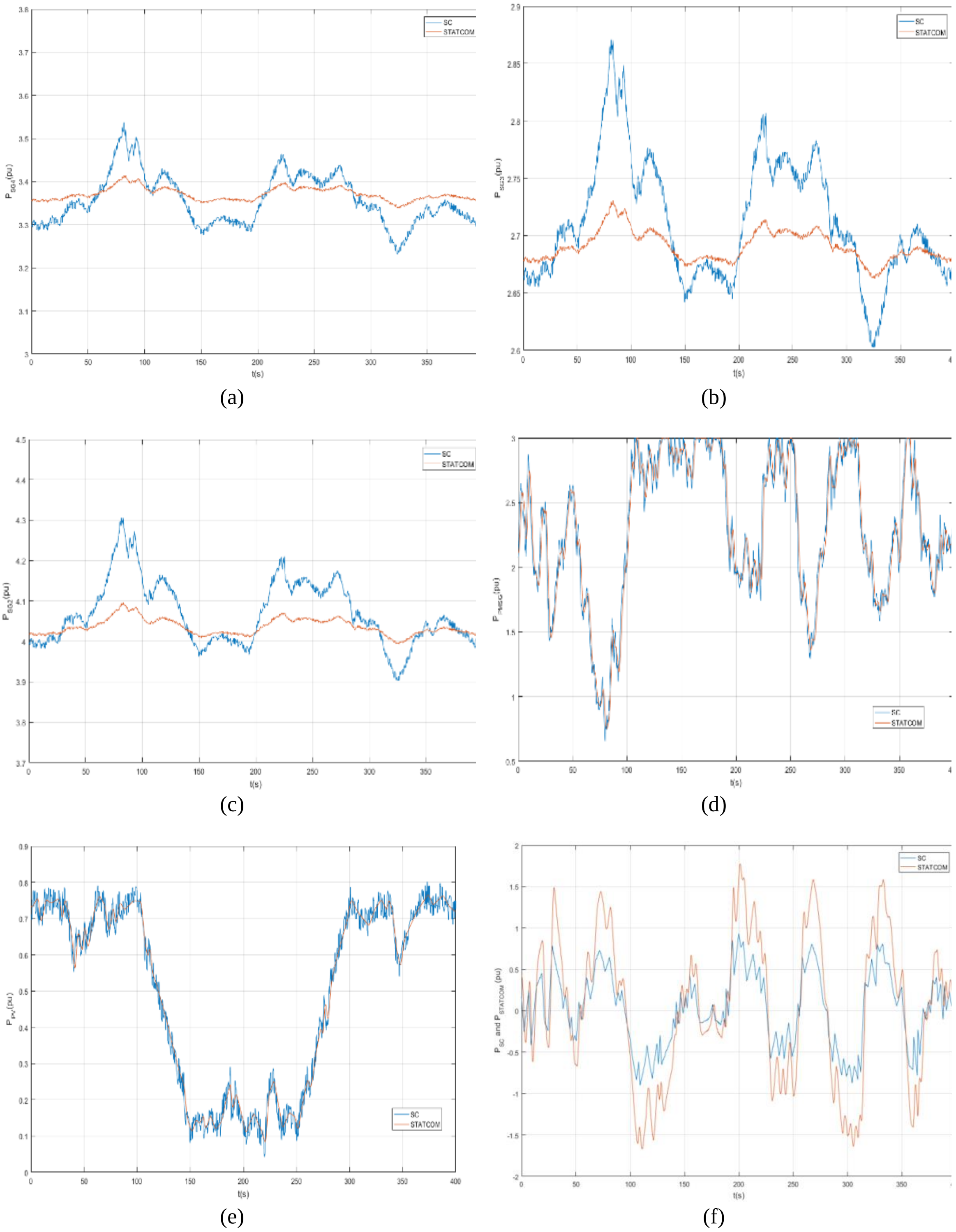

Figure 7. Dynamic reaction of considered framework under concurrent varieties of both wind speed and sunlight-based irradiance comparison of SC and STATCOM (a) PSG4, (b) PSG3, (c) PSG2, (d) PPMSG, (e) PPV, and (f) PSC and PSTATCOM

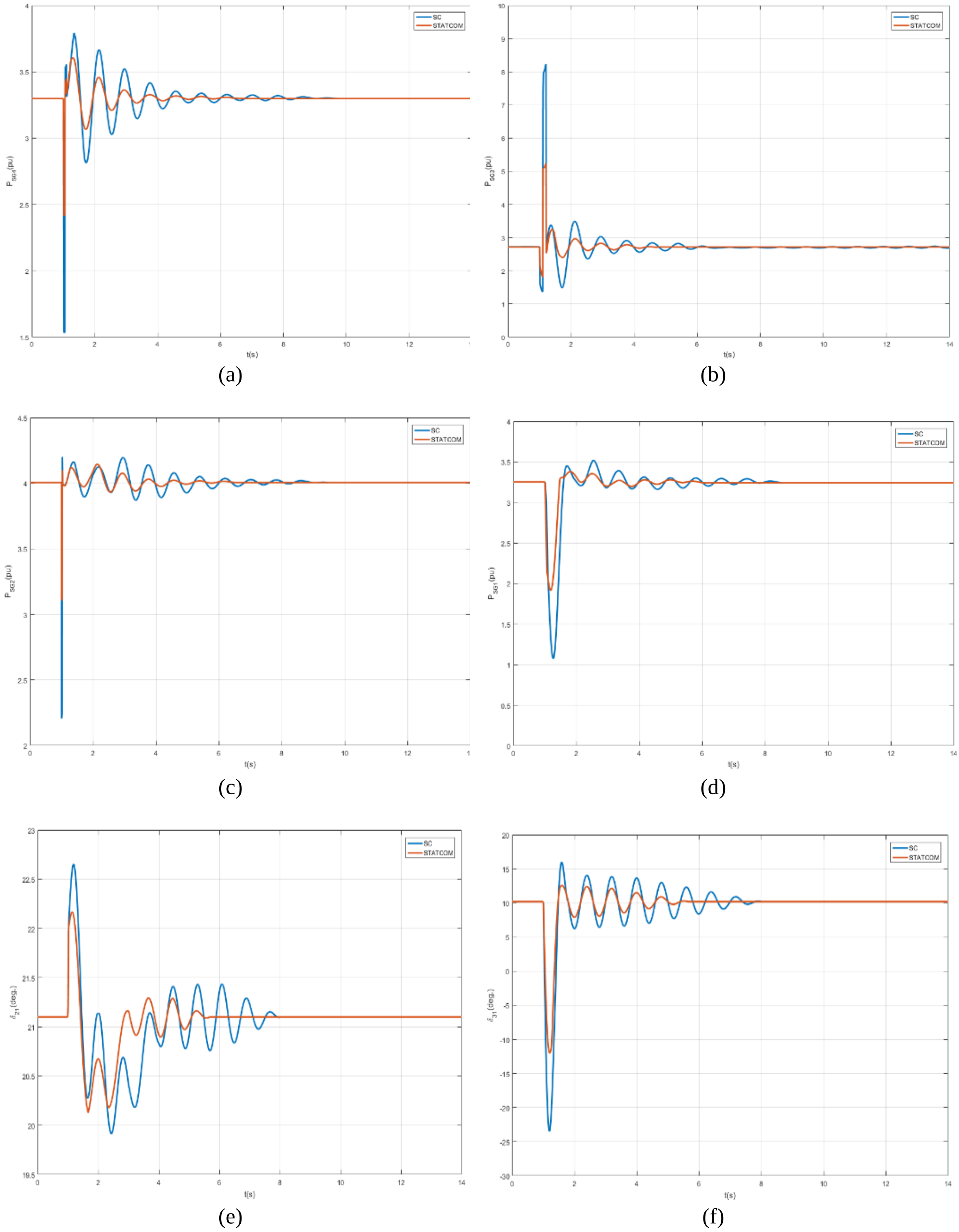

Figure 8. Relative transient reaction of contemplated framework among SC and STATCOM (a) PSG4, (b) PSG3, (c) PSG2, (d) PSG1, (e) δ21, and (f) δ31

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