ANN APPLICATION ON A SIMPLE ACTIVE AND REACTIVE POWER CONTROL OF A SINGLE PHASE ELECTRIC SPRING

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Abstract: Artificial neural nets (ANNs) are massively parallel systems with large numbers of interconnected simple processors. Electricity is being produced in large amount with power plants with coal, oil as primary source and use of these fuels results in increasing pollution and green house problems. Day by day increasing consumption of these fuels is leading towards the extinction of these conventional fuel sources. Now a days nonconventional energy sources are being installed in modern power systems worldwide to solve the crisis of fossil fuels. But the penetration of these non-conventional sources in the power system affects the quality and stability of system in adverse manner. This paper presents an effective concept called Electrical Spring to regulate the mains voltage despite of fluctuations caused due to intermittent nature of renewable energy sources using different types of control techniques. This technology reduces the voltage fluctuations on grid and stabilizes the power system with substantial penetration of intermittent renewable energy sources in distribution systems by using artificial neural networks (ANN). ANNs determine the appropriate system topology that reduces the power loss according to the variation of load pattern. The control strategy can be easily obtained on the basis of the system topology which is provided by ANNs.

IndexTerms **–Electric spring, ANN, Renewable energy**

1. INTRODUCTION

Centralized control is adopted in the existing power system where power generation mainly depends on the load prediction. Nowadays, with the increasing portion of power generated from the renewable energy sources (RESs) and injected into the power system, stability issues become more and more severe due to the RES intermittency.Flexible alternating current transmission systems are used to control voltage and/or power flow.

However, most of them are suitable for high- or medium-voltage applications, and cannot be used for future low-voltage microgrids with high RES penetration, such as roof photovoltaic (PV) and small power-rating wind plants. To cope with this need, the electric spring (ES) technology has been proposed for future distributed microgrids to transfer the line voltage fluctuations to the so-called non-critical loads (NCLs), i.e. to the loads that tolerate a large supply voltage range, so as to keep regulated the voltage across the so-called critical loads (CLs), i.e. the loads that tolerate a narrow supply voltage range. The transfer occurs through an automatic balance of the load demand with the power generation, performed by ES. The set made of ES and NCLs forms the so-called smart load (SL).

The voltage across CLs and the in-parallel SL is hereafter designated with grid voltage. So far, many project s have appeared reporting on ES topologies and their control strategies. The first version (ES-1) can only manage the reactive power whilst the second version (ES-2) can manage both the active and the reactive power as the capacitor in the DC side of ES is replaced by a voltage source like a battery pack.For instance, proposes the control of the input current by resorting to the dq0-transformation. This solution, however, is unable to keep unaltered the grid voltage as it is regulated in an open-loop mode. Even if a closed-loop with a ANN (artificial neural network) regulator is added to regulate the grid voltage, it mainly takes care of the power factor correction rather than of the voltage regulation. In the δ control is proposed to adjust the instantaneous phase of CL voltage but relies on system modeling that utilizes the circuitry parameters. Recently, the radial-chordal decomposition (RCD) control is proposed in to decouple the control of the power angle of SL from the voltage across CL, which makes ES-2 ready to be embedded in many devices such as water heaters. However, it still has some shortcomings. For instance, the power angle of NCL should be known in advance, which prevents the use of the RCD control when NCL varies or is non-linear. Besides, it is difficult to obtain pure reactive power compensation by means of ES. Power control of ES-2 is studied in this project with reference to a practical application.Let us consider a low power outdoor wind power plant as an example The maximum power point tracking (MPPT) technique is normally adopted in the wind and/or solar power generation plants .The tracked active power is consumed by the electrical loads at domestic homes, which are of both CL and NCL types. For an ES installed at the same location as the wind power plant, the active and reactive powers generated by the plant can be measured by ES even if they are changing quickly. As a result, ES in such situation can carry out the control.

II. OPERATING PRINCIPLES OF ES-2

2.1. ES-2 Topology.

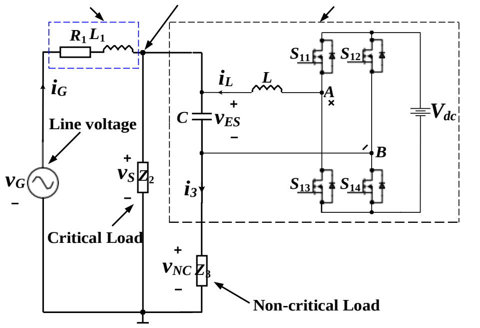
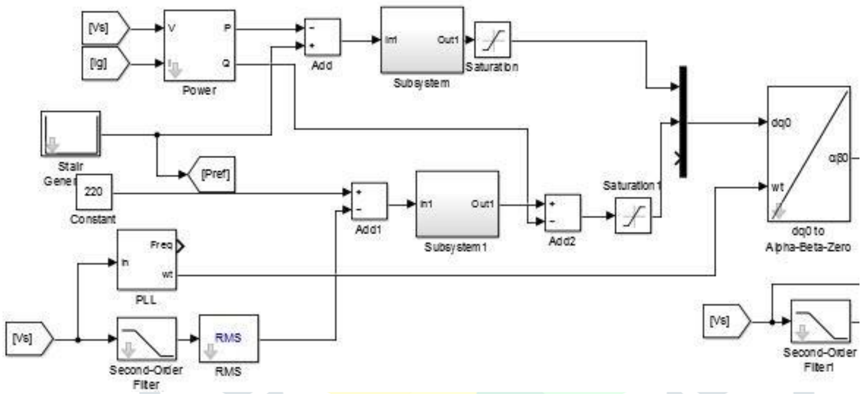


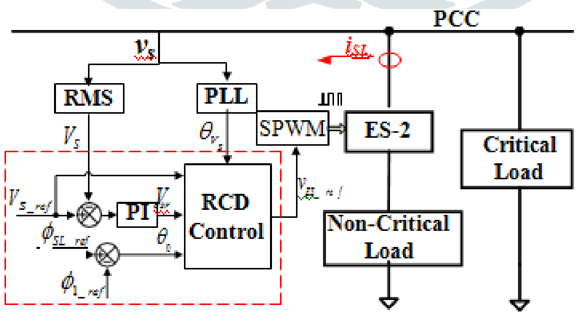
Figure 2.1 Topology of ES-2 and associated circuitry.

The topology of ES-2 and the associated circuitry are drawn in Fig.1. In this figure, ES-2 is enclosed by the dashed line and consists of a single-phase voltage source inverter (VSI), an L filter and a capacitor whose voltage sums up to that of the NCL. Moreover, Z_2 is the CL, Z_3 is the NCL, v_G represents the line voltage of the power system with RESs, R_1 and L_1 are the line resistance and inductance, respectively. The branch including v_G and the line impedance supplies CL and SL. v_S denotes the voltage of point of common coupling (PCC), which is also the CL voltage

2.2. CONTROL SCHEME OF PROPOSED SYSTEM



(a)



(b)

Figure 2.3 ES-2 control diagram for (a) δ control, (b) RCD control

III. THE PROPOSED POWER CONTROL

In this section, the proposed power control is presented, explaining its ability to achieve a simple active and reactive power control for ES-2 by a local signal manipulation. In the proposed control, the single-phase *dq* rotating frame is adopted

3.1 Active and reactive power of ES system

The sinusoidal voltage v_S(t) and current i_1(t) can be expressed as

$$v_S(t)=\sqrt{2}V_S\cos(\omega t+\phi) \quad (1)$$

$$i_1(t)=\sqrt{2}I_1\cos(\omega t+\psi) \quad (2)$$

where ϕ and ψ are the initial phases, ω is the angular frequency,

V_S and I_1 denote the rms value of $v_S(t)$ and $i_1(t)$, respectively. By looking from PCC to the right side in active, reactive and apparent powers can be expressed from (3) to (5) where P_{in} And Q_{in} vector form of

$$\tilde{S} = \vec{V}_S \cdot \vec{I}_1 = V_S I_1[\cos(\phi - \psi) + j\sin(\phi - \psi)] = P_{in} + jQ_{in} \quad (3)$$

Where

$$P_{in} = V_S I_1 \cos(\phi - \psi) \quad (4)$$

$$Q_{in} = V_S I_1 \sin(\phi - \psi) \quad (5)$$

The active and reactive power can be represented in terms of the variables on a rotating frame as

$$P_{in} = v_d i_d + v_q i_q \quad (6)$$

$$Q_{in} = v_q i_d - v_d i_q \quad (7)$$

Where v_d and v_q are the components of v_S in the dq rotating frame/the same analogy applies to i_d and i_q. If the voltage vector of v_S is aligned along the d-axis of the rotating frame, (6) and (7) can be rewritten as

$$P_{in} = v_d i_d \quad (8)$$

$$Q_{in} = -v_d i_q \quad (9)$$

The matrix for the transformation of a vector from the $\alpha\beta$ stationary frame to a dq rotating frame and its inverse are expressed as

$$T(\hat{\theta}) = \begin{bmatrix} \cos\hat{\theta} & \sin\hat{\theta} \\ -\sin\hat{\theta} & \cos\hat{\theta} \end{bmatrix} \quad (10)$$

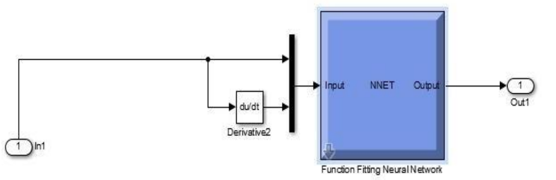
$$T(\hat{\theta})^{-1} = \begin{bmatrix} \cos\hat{\theta} & -\sin\hat{\theta} \\ \sin\hat{\theta} & \cos\hat{\theta} \end{bmatrix} \quad (11)$$

Where $\hat{\theta}$ is the instantaneous phase of the PCC voltage detected by a phase locked loop (PLL) block.

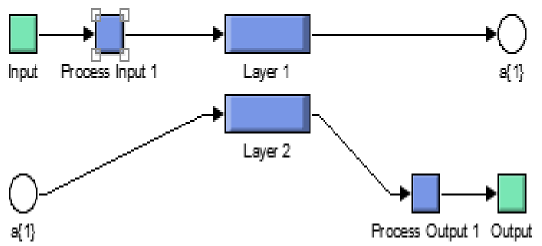
3.2. Artificial neural network (ANN)

A feed-forward network is adopted here as this architecture is reported to be suitable for problems based on pattern identification. A network first needs to be trained before interpreting new information. Several different algorithms are available for training of neural networks, but the back-propagation algorithm is the most versatile and robust technique for it provides the most efficient learning procedure for multilayer neural networks.

Also, the fact that back-propagation algorithms are especially capable to solve problems of prediction makes them highly popular During training of the network, data are processed through the network until they reach the output layer (forward pass). In this layer, the output is compared to the measured values (the \true" output). The difference or error between the two is processed back through the network (backward pass) updating the individual weights of the connections and the biases of the individual neurons. The input and output data are mostly represented as vectors called training pairs. The process as mentioned above is repeated for all the training pairs in the data set, until the network error has converged to a threshold minimum defined by a corresponding cost function, usually the root mean squared error (RMSE).



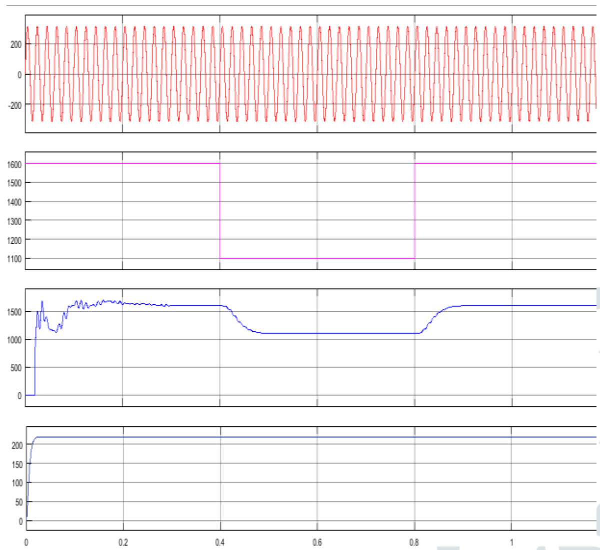
Block diagram of ANN



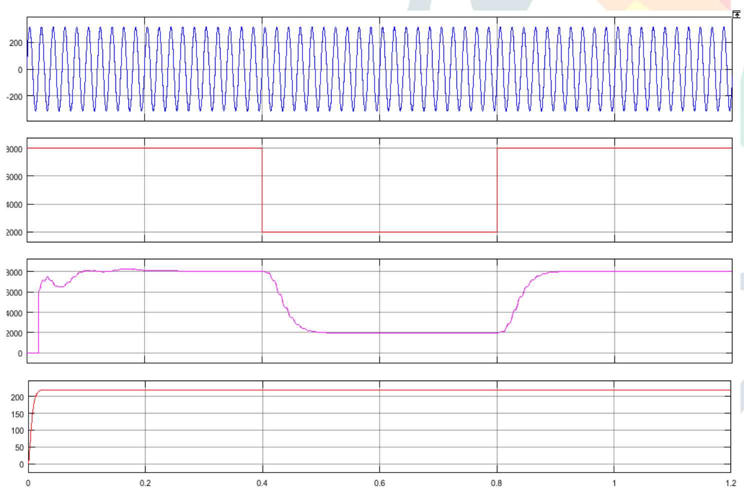
IV SIMULATION RESULT :

A . Input Active Power Variation

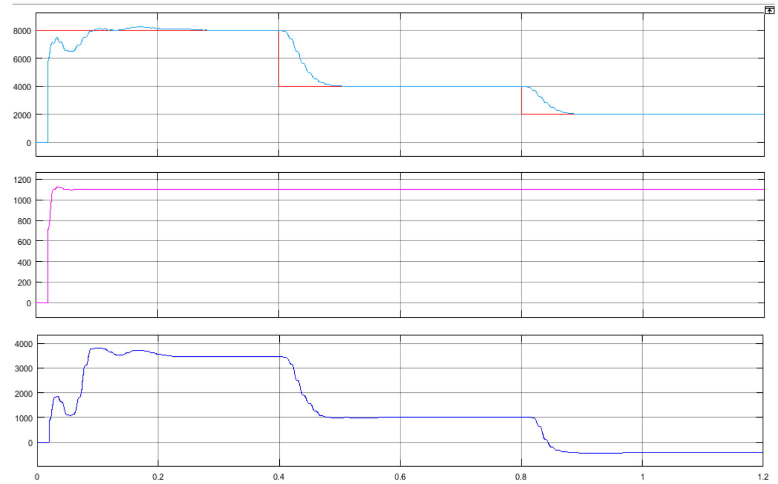
In this part, three different values are selected for V_G to monitor its behavior when P_{inref} varies is shows the simulation results when P_{inref} varies. In each subfigure, four channels are recorded, reporting v_G, P_{inref}, P_{in} and RMS value of the CL voltage, respectively. Results in a full time range are also shown in Fig. 5(a), in which P_{inref} is changed from 1.6kW to 1.1kW at 0.4s and then back to 1.6kW at 0.8s. It is observed that P_{in} tracks P_{inref} well while V_S is regulated to 220V as P_{inref} varies, setting V_G=200 as an example. In each subfigure, four channels are recorded, reporting P_{in}, P_{CL}, P_{ES} and P_{NCL} against their pre-set values.



(a) Simulation waveforms under different variations of the input active power.
From 1.6kW to 1.1kW and then back to 1.6kW @ *VG*=230V



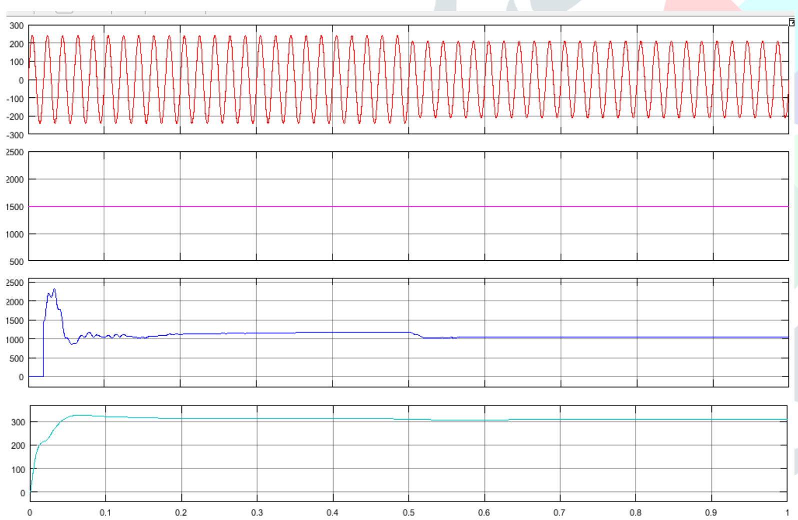
(b)From 8KW to 2KW and then back to 8KW



(c) From 8KW to 4KW and then to 2KW@ V_G=200V.

B. Line Voltage Variation

In this Subsection, the ES-2 transient responses to a change of V_G are monitored with P_{inref} fixed. They are traced in (a) and (b). In each subfigure, four channels are recorded, reporting line voltage, reference value of the input active power,input active power and RMS value of CL voltage, respectively (a), V_G is changed between two different values, more specifically it is equal to 240V from 0 to 0.5s; afterwards it jumps to 210V at 0.5s and remains at this value up to 1s. The change of V_G in (b) is the opposite of that in (a) In both the simulations, P_{inref} is set to 1.5kW and P_{in} remains at the pre-set value very accurately. Meanwhile, the RMS value of the CL voltage is regulated to 220V as required

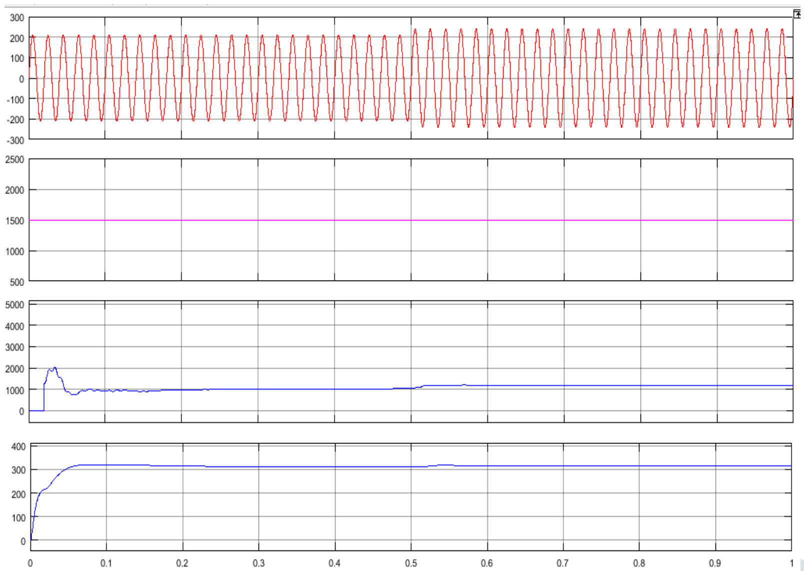


(a)

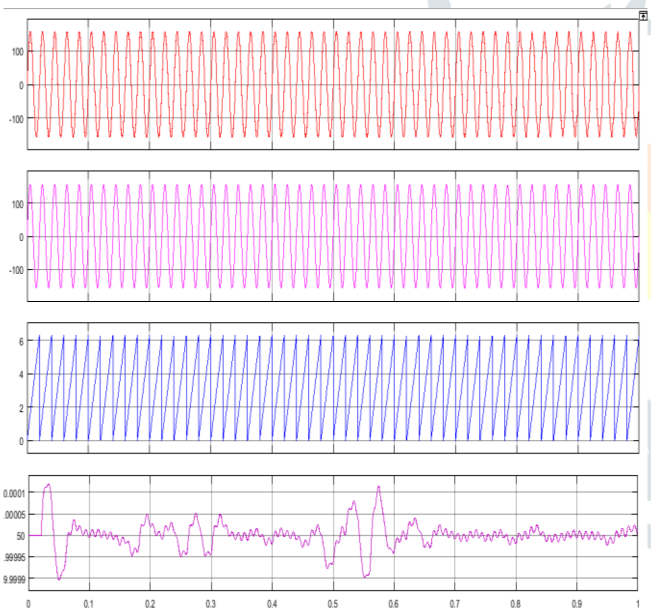
(a) Transient ES-2 responses to a change of the line voltage with P_{inref}=1.5kW from 240V to 210V.

TABLE I

Items	Values
Regulated PCC voltage (V_S)	220V
DC bus voltage (V_{dc})	400V
Line resistance (R_1)	0.1Ω
Line inductance (L_1)	2.4mH
Critical load (R_2)	43.5Ω
Non-critical load (R_3)	2.2Ω
Inductance of low-pass filter (L)	3mH
Capacitance of low-pass filter (C)	50µF
Switching frequency (f_s)	20kHz



(b) a change of the line voltage with P_{inref}=1.5kW from 210V to 240V



Simulation waveforms before and after grid distortion.Results of PLL.

V. Conclusion

The input active and reactive power control is proposed for the purpose of practical application of ES-2 in this paper, the ES-2 can manage the fluctuated power and make sure the controllable power to grid by control stratagies. Tested simulation results have validated the proposed control. Intelligent control approach (ANN controller) with inclusion of slider gain provides better dynamic performance and reduces the oscillation of the frequency deviation and the active and reactive power is controlled. The ANNs are quite flexible for adaption to different type of problems and can be custom-designed to almost any type of data representations.

REFERENCES

[1] M. Cheng and Y. Zhu, "The state of the art of wind energy conversion systems and technologies: Areview," Energy Conversion and Management, vol. 88, pp. 332–347, Dec. 2014.

[2] P. Sotoodeh and R. D. Miller, "Design and implementation of an 11-level inverter with FACTS capability for distributed energy systems," IEEE J. Emerging Sel. Topics Power Electron., vol.2, no. 1, pp. 87–96, Mar. 2014.

[3] L. Wang, and D. N. Truong, "Stability enhancement of a power system with a PMSG-based and a DFIG-based offshore wind farm using a SVC With an adaptive-network-based fuzzy inference system," IEEE Trans. Ind. Electron., vol. 60, no. 7, pp. 2799–2807, Jul. 2013.
[4] Y. Zhang, X. Wu and X. Yuan, "A simplified branch and bound approach for model predictive control of multilevel cascaded H-bridge STATCOM," IEEE Trans. Ind. Electron., vol. 64, no. 10, pp. 7634–7644, Oct. 2017.
[5] W. Wang, L. Yan, X. Zeng, B. Fan, and J. M. Guerrero, "Principle and design of a single-phase inverter based grounding system for neutral-to-ground voltage compensation in distribution networks," IEEE Trans. Ind. Electron., vol. 64, no. 2, pp. 1204–1213, Feb. 2017.
[6] Q. Sun, J. Zhou, J. M. Guerrero, and H. Zhang, "Hybrid three-phase/single-phase microgrid architecture with power management capabilities," IEEE Trans. Power Electron., vol. 30, no. 10, pp. 5964– 5977, Oct. 2015.
[7] J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. de Vicuna, and M. Castilla, "Hierarchical control of droop-controlled AC and DC microgrids—a general approach toward standardization," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 158–172, Jan. 2011.
[8] S. Y. R. Hui, C. K. Lee, and F. Wu, "Electric springs—A new smart grid technology," IEEE Trans. Smart Grid, vol. 3, no. 3, pp. 1552–1561, Sept. 2012.
[9] S. C. Tan, C. K. Lee, and S. Y. R. Hui, "General steady-state analysis and control principle of electric springs with active and reactive power compensations," IEEE Trans. Power Electron., vol. 28, no. 8, pp. 3958– 3969, Aug. 2013.
[10] C. K. Lee and S. Y. R. Hui, "Input AC voltage control bi-directional power converters," U.S. Patent 13/907, 350, May 31, 2013.
[11] Q. Wang, M. Cheng, G. Buja, and Z. Chen, "A novel topology and its control of single-phase electric springs," in Proc. Int. Conf. Renewable Energy Res. Appl., 2015, pp. 267–272.
[12] Q. Wang, M. Cheng, and Y. Jiang, "Harmonics suppression for critical loads using electric springs with current-source inverters," IEEE J. Emerging Sel. Topics Power Electron., vol. 4, no. 4, pp. 1362–1369, Dec. 2016.
[13] S. Yan, S. C. Tan, C. K. Lee, and S. Y. R. Hui, "Electric spring for power quality improvement," in Proc. IEEE Appl. Power Electron. Conf. Expo., 2014, pp. 2140–2147.
[14] Q. Wang, M. Cheng, Z. Chen, and Z. Wang, "Steady-state analysis of electric springs with a novel δ control," IEEE Trans. Power Electron., vol. 30, no. 12, pp. 7159–7169, Dec. 2015.
[15] K. T. Mok, S. C. Tan, and S. Y. R. Hui, "Decoupled power angle and voltage control of electric springs," IEEE Trans. Power Electron., vol. 31, no. 2, pp. 1216–1229, Feb. 2016.