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DISTRIBUTED PHOTOVOLTAIC ELECTRIC SPRING SYSTEM FOR POWER BALANCER IN POWER DISTRIBUTION NETWORKS

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Abstract—Electric springs (ES) have been proposed as a demand-response technology for improving the stability and power quality of emerging power systems with high penetration of intermittent renewable energy sources. Existing ES applications mainly involve the regulations of grid voltage and utility frequency. This paper reports a power control and balancing technique for a new integrated configuration of ES and photovoltaic (PV) system, and discusses its possible use to achieve dynamic supply–demand balance in power distribution networks. The proposed system enables delivery of maximally harvested PV power to the grid via the ES, and concurrently controls the active power consumption of its ES associated smart load so as to achieve supply–demand power balance of the overall system in real time. Importantly, battery storage is not necessary in the proposed design because the ES-associated smart-load power follows an appropriate consumption profile to compensate potential prediction errors of the PV power generation. Both simulation and experimental results are included to validate the proposed ES system.

1. INTRODUCTION

Electric power is the most important energy source for human beings. It securely and stably supplies costumers with by power system. A complete power system is consisted of power generators, step-up and step-down transformers, overhead or underground transmission lines and sub transmission lines, distribution cables and switchgear. According to their functions, those components of power system can be categorized into three segments.

The first part is the generation system, in which the electricity is produced from large power plants owned by power companies or independent suppliers. Since the voltage level of the generated power follows the rated voltage setting of generators, in order to transmit the power over long distance with minimum power loss step-up transformers are utilized to increase the voltage. The second part is the transmission system, the function of transmission system is to deliver the power from generation system to load center via cables or overhead transmission lines. In order to reduce power loss, the power transmitted is at extra high voltage level in both transmission network and subtransmission network. The third part is the distribution system. The power voltage is firstly decreased to medium voltage (MV) level by step-down transformers at terminal substations.

Then the power is transmitted by distribution lines or cables to local substations after its voltage is further reduced to consumer level. At this stage, the electricity can be directly

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delivered to residential customers, commercial establishments and industry segments. In order to acquire a better understanding of the physical arrangement of the power system, a typical system which supplies electricity to a big city is taken as an example. In generation stage, the power plants are usually located far away from the urban area to avoid pollution. In transmission stage, the transmission lines or underground cables are used to transmit electricity from the power stations to terminal substations.With increasing awareness on global warming issues andenergy crisis, different forms of distributed energyresources (DER) such as photovoltaic (PV) power generations, micro wind turbines, electrical vehicles (EV), and fuel cells have been deployed into powergrids over the last decades. With the advantages of a rapidlyreduced cost and no rotational parts, PV powergeneration systems have become an important distributedgeneration (DG) in low-voltage distribution networks (LV-DNs)for residential and industrial applications. DistributedPV power generation systems are currently growing at anunprecedented speed. In the past decade, the global PV powercapacity has surged from 6 GW in 2006 to more than 300 GW in 2016.There are several strategies to address variable generation. Thetraditional approach is to use dispatchable units already in the system,such as hydropower or conventional fossil-fuelled power plants. Analternative is the use of demand-side management (DSM) techniques,whereby electricity consumption is controlled, either by sheddingload or shifting it in time. Storage of electricity, e.g., in batteries orpumped hydro storage, can also be used to manage variations in generation.Finally, and of most relevance to the present work, variabilitycan be handled using the electric grids.

2. LITERATURE SURVEY

Y. Karimi, H. Oraee, M. S. Golsorkhi, and J. M. Guerrero[1], proposes a new decentralized power management and load sharing method for a photovoltaic based islanded microgrid consisting of various photovoltaic (PV) units, battery units and hybrid PV/battery units. Unlike the previous methods in the literature, there is no need to communication among the units and the proposed method is not limited to the systems with separate PV and battery units or systems with only one hybrid unit. The proposed method takes into account the available PV power and battery conditions of the units to share the load among them. To cover all possible conditions of the microgrid, the operation of each unit is divided into five states and modified active power-frequency droop functions are used according to operating states. The frequency level is used as trigger for switching between the states.

F. Blaabjerg, Y. Yang, D. Yang, and X. Wang[2], Continuously expanding deployments of distributed power-generation systems (DPGSs) are transforming the conventional centralized power grid into a mixed distributed electrical network. The modern power grid requires flexible energy utilization but presents challenges in the case of a high penetration degree of renewable energy, among which wind and solar photovoltaics are typical sources. The integration level of the DPGS into the

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grid plays a critical role in developing sustainable and resilient power systems, especially with highly intermittent renewable energy resources. To address the challenging issues and, more importantly, to leverage the energy generation, stringent demands from both utility operators and consumers have been imposed on the DPGS. Furthermore, as the core of energy conversion, numerous power electronic converters employing advanced control techniques have been developed for the DPGS to consolidate the integration. In light of the above, this paper reviews the power-conversion and control technologies used for DPGSs.

X. Wang and Q. Liang[3], As a paradigm of the incoming smart grid, vehicleto-grid (V2G) has been proposed as a promising solution to increase the adoption rate of plug-in hybrid electric vehicles (PHEVs). In this paper, we investigate the energy management strategies for PHEVs via bidirectional V2G. We first follow a costconscious approach from the PHEV owner point of view. To minimize the daily energy cost, we formulate the energy management problem via dynamic programming (DP). However, the "wellknown" complexity in solving DP poses a computational challenge even for a small number of iterations. Therefore, we propose a state-independent four-threshold (s, S, s', S') battery charging/ discharging policy and theoretically prove the optimality of the proposed energy management strategy based on stochastic inventory theory. A backward iteration algorithm is further developed to practically implement the (s, S, s', S') feedback policy. Second, from the distribution system operator's perspective, we aim to shave the peak load and flatten the overall load profile. To this end, we propose an optimal PHEV charging scheme and further derive a reminiscent "water-filling" solution for this scenario. Realistic PHEV battery models, time-of-use electricity pricing rate, and real data of household demand are integrated into our formulated V2G system model.

C. Wang, X. Yang, Z. Wu, Y. Che, L. Guo, S. Zhang, and Y. Liu[4], A highly integrated and reconfigurable microgrid testbed is presented in this paper. The microgrid testbed contains various distributed generation units and diverse energy storage systems. Apart from electrical power, it can also provide energy in forms of hydrogen and thermal energy. The topology of this testbed is very flexible with different combinations of buses and feeders. The deployment of hybrid distributed energy sources and the highly reconfigurable structure are available to meet different research requirements. Extensive experiments have been carried out to provide verification for microgrid research and guides for microgrid projects.

Y. Han, H. Li, P. Shen, E. A. A. Coelho, and J. M. Guerrero[5], Microgrids consist of multiple parallel-connected distributed generation (DG) units with coordinated control strategies, which are able to operate in both grid-connected and islanded modes. Microgrids are attracting considerable attention since they can alleviate the stress of main transmission systems, reduce feeder losses, and improve system power quality. When the islanded microgrids are concerned, it is important to maintain system stability and achieve load power sharing among the multiple parallel-connected DG units. However,

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the poor active and reactive power sharing problems due to the influence of impedance mismatch of the DG feeders and the different ratings of the DG units are inevitable when the conventional droop control scheme is adopted. Therefore, the adaptive/improved droop control, network-based control methods, and cost-based droop schemes are compared and summarized in this paper for active power sharing. Moreover, nonlinear and unbalanced loads could further affect the reactive power sharing when regulating the active power, and it is difficult to share the reactive power accurately only by using the enhanced virtual impedance method. Therefore, the hierarchical control strategies are utilized as supplements of the conventional droop controls and virtual impedance methods. The improved hierarchical control approaches such as the algorithms based on graph theory, multi-agent system, the gain scheduling method, and predictive control have been proposed to achieve proper reactive power sharing for islanded microgrids and eliminate the effect of the communication delays on hierarchical control.

3 PROBLEM FORMULATION

The high penetration of distributed PV power generation systems in LV-DNs inevitably challenges current ways where the traditional distribution grid is planned and operated. The traditional infrastructure of the power distribution networks is designed to accept only unidirectional power flow from the substation to the households. However, with the distributed PV power generations adopted in LV-DNs, there is a potential reversal of power flow from households to a substation due to the excessive PV power that may be generated in sunny daytime. Substantial reverse-power flows could cause the problems of over-voltage and grid voltage fluctuations. Such problems may result in incorrect operation of protective devices, damage of grid-tied equipment, reduction in system reliability and utility frequency stability, and even power blackouts. In summary, excessive voltage rise and the supply-demand power imbalance are two emerging problems in increasing deployment of distributed PV systems to the power distribution networks. Various solutions have been suggested to overcome the over-voltage or power imbalance problems. These solutions can be categorized into (i) the traditional tap-changing approaches, (ii) the reactive power compensation, (iii) the PV power generation curtailment, (iv) the adoption of battery energy storage systems (BESS), and (v) the demand-side management.

4.SYSTEM MODELING

A schematic of a PV system connected to the point ofcommon coupling (PCC) is shown in Fig. 4.1. The power grid isrepresented as a power source Vs including a distribution line Zson the supply side. A load R1 and a PV system as shown in Fig.4.1 are considered on the demand side. Vg denotes the voltageRMS magnitude of PCC. The PV system is made up of a PVpanel array, and an interfacing power inverter that converts andtransfers the harvested renewable power (Ppv) to the power grid.

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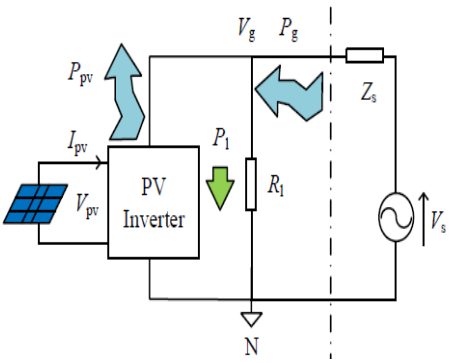

Fig. 1. The simple power grid with a conventional PV system installed. (Thezigzag arrows indicate the uncertain power generations while the normal arrowindicates a stable power consumption.)

The load R1, consuming a real power P1, represents the powerconsumption on the demand side.The PV power generation at the demand side is predicted asPpv_Ref, and hence an expected supply-side power reference isestimated (Pg_Ref = P1 − Ppv_Ref). Due to the uncertainty of thePV power generation, the PV power prediction is a greatconcern for the operators of the energy management inelectricity networks with high integration of PV power.Accurate forecasting based on real-time measurements andrecords is helpful for operators to reduce the impact of thevariability of PV power on the grid, and to improve the gridreliability. However, such kinds of forecasting are easilyinfluenced by the external conditions (such as the weather,temperature, and presence of dust). Therefore, the intermittentnature of PV generation still leaves inevitable errors betweenthe predicted power (Ppv_Ref) and actual power (Ppv). Since thesupply-side reference is based on the forecasting, such errorscause the power imbalance between the supply and demandsides.

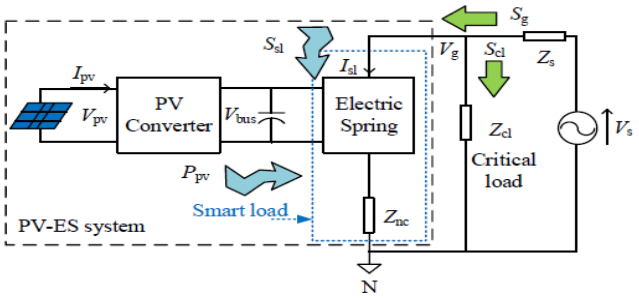

Fig. 2.A simplified diagram of the PV-ES system.

As a supply-demand power balancer, the proposed PV-ESsystem, as shown in Fig. 4.2, consists of a PV panel array, a PVconverter, an ES, and an NC load. In the usual PV harvestingprocess, the DC power output of the PV converter forms the DC voltage for the ES. The equivalent impedance of the NC load isdenoted as Znc. The remaining loads (not including Znc) in thispower grid can be combined into a single critical load denotedas Zcl. In this paper, we assume a heating or cooling system,which is purely resistive, as the NC load. With thecharacteristics of (i) being readily available throughout the 24-hour timeframe, (ii) having a great storage inertia in forbuffering voltage fluctuation, and (iii) being a widespreadappliance commonly available in most of the buildings, suchthermal loads are ideal NC candidates for ES applications. Thecomplex power consumed by the ES, the NC load, the criticalload, and the ES-associated smart load are respectively denotedas Ses = Pes + jQes, Snc = Pnc + jQnc, Scl = Pcl + jQcl, and Ssl = Psl+ jQsl (all symbols stand for magnitudes). For the ease ofexplanation in the subsequent analysis, the critical load is alsochosen to be purely resistive (Qnc = Qcl = 0).There are two main objectives of using such PV-ESconfiguration. First,

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the ES should regulate the demand-sideactive power to be a desired value (a value determined by theupper level to maintain a constant power consumption forpower balance, or to adjust the power consumption toparticipate in voltage/frequency regulation, etc.) irrespective ofthe fluctuation of the PV power generation. Second, the PVsystem and the ES should collaborate properly in such a waythat the system can transfer the intermittent PV power to thegrid without the need of battery storage. To handle the desiredPV power delivery and to adaptively regulate the powerconsumption of the smart load simultaneously, two powerreferences, (i) the ES active power reference (Pes_Ref) and (ii)the ES-associated smart-load active power reference (Psl_Ref)are required in the proposed control strategy. Based on theassumption that the power loss of the power converters isignored in the analysis, and the fact that the PV converter islinked to the ES converter as shown in Fig. 4.2, the amount of theharvested PV power (Ppv) should be equal to that of the ESactive power delivered to the power grid (−Pes)1.In the proposed control scheme, the power consumption ofthe ES-associated smart load should be adjustable irrespectiveof the PV power fluctuation. The operation point of ES with agiven value of Psl can be derived based on the radial-chordal decomposition (RCD) method.

A. Power-Stage Design

The power-stage schematic of the proposed PV-ES system isshown in Fig. 3. The PV interfacing power converter isimplemented by an active clamp flyback DC/DC converter,which is used for harvesting PV power with maximum powerpoint tracking (MPPT) control and stepping up the PV panelvoltage (Vpv) to be the DC bus voltage (Vbus). As shown in Fig.4.3, the circuit components T1, Sa2, C1, and D1 form a conventionalflyback DC/DC power converter. Ca and Sa1 is added to theconverter as an active clamp circuit. In addition, D2 and C2 areadded to form a voltage multiplier circuit, which doubles thevoltage conversion ratio. The input voltage (Vpv) and inputcurrent (Ipv) of this flyback converter are sensed to achieveMPPT.

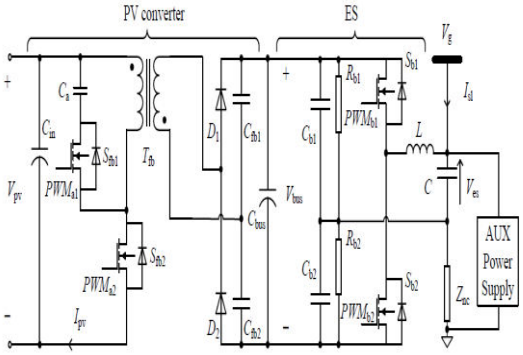

Fig. 3.The power-stage schematic of the proposed PV-ES system.

The ES is realized by a conventional half-bridge DC/ACpower converter, which composes Cb1, Cb2, Sb1, and Sb2. The DCbus of the ES is connected to the output of the PV interfacingpower converter while the AC port of the ES is connectedbetween PCC and the NC load (Znc). Rb1 and Rb2 are added tothe power stage of the ES (where Rb1 = Rb2) to avoid capacitorvoltage imbalance on Cb1 and Cb2. Real-time voltages of Vbus,Ves, and Vg are sensed and used for the purpose of feedbackcontrol. The auxiliary DC power supply for the DSP, sensors,and driver ICs are obtained from the grid AC power, of whichthe details will not be discussed.

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B. Controller Design

The controller design of the PV converter and the ES isdiscussed in this section. Both the controllers are implementedin a single PWM. The control blockdiagram of the PV-ES system is shown in Fig. 4.4.

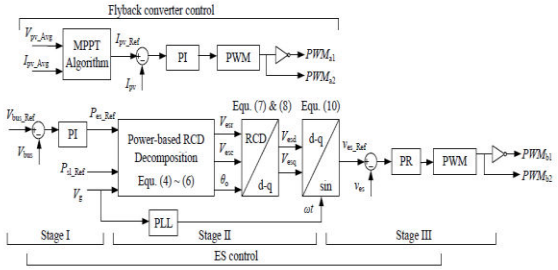

Fig. 4.The control scheme of the PV-ES system.

For the PVconverter, the input current (Ipv) is regulated by a PI controller.A PV current reference (Ipv_Ref) is obtained from the MPPTalgorithm. As this paper focuses on the power managementrather than the solar power harvesting method, simple PVcurrent-voltage and power-voltage characteristics areconsidered (in which there is only one maximum power pointon the PV power curve), and a current-based incrementalconductance algorithm is adopted in this paper for the MPPTcontrol (whose details are omitted). The output signal of the PIcontroller is used to generate a pair of the 20-kHzcomplimentary PWM signals (PWMa1 and PWMa2) for drivingthe MOSFET Sa1 and Sa2, respectively.The control process of the ES voltage controller comprisesthree stages, which are the power reference update (Stage I), theES voltage reference calculation (Stage II), and the ES voltageregulation (Stage III).

In Stage I, the ES active power reference, Pes_Ref, is generatedby a PI controller. This PI controller is used to stabilize the DCbus voltage by comparing the sensed Vbus with the constant DCbus reference (Vbus_Ref) when the PV converter is operating.Stabilizing Vbus requires co-operation of the PV converter andES. The fluctuation of Vbus indicates the power imbalancebetween the harvested PV power and the real power ESdelivered. For example, if Vbus is higher than Vbus_Ref, it indicatesmore PV power is harvested than that of ES delivered into thegrid, and hence the magnitude of Pes_Ref increases in order torestore Vbus. Note that when the PV converter is disabled and noPV power is delivered to the output, the ES provides purelyreactive power only to control Psl. In this case, the DC voltageis not regulated to Vbus_Ref but allowed to vary according to thechange of Ves.In practice, a θoleading to less reactive power shift may be preferred, as itconducts less transfer of reactive power, and reduces the outputvoltage of ES. These benefit the DC bus voltage control in StageI, since the fluctuation caused by reactive power and thevoltage-level requirement on components can be reduced.Choosing such a feasible operation point depends on the NCload itself. For instance, if the NC load is capacitive ($\phi nc < 0$),then θo is the sum of the angular components as indicated in (6).In the condition where Znc is purely resistive, both the choicesresult in the same level of reactive power shift. Therefore, θocan be alternatively chosen for qualitative compensation usingeither capacitive- or inductive-reactive power.

5.SIMULATION RESULTS

In this section, the proposed control methodology is first applied to a PV-ES system for a period of 0.4 s that iscompressed from a 1s record. Secondly, the proposed PVESsystem is compared with the conventional PV

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plus BESS(PV+BESS) solution, and that of the three different existingversions of ES.

CASE-A: POWER PROFILES

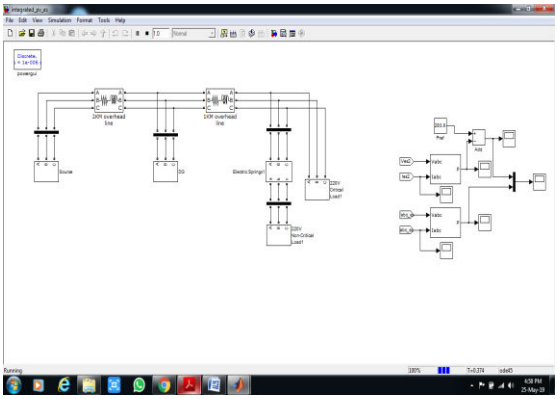


Fig:5. Simulation diagram of ES-PV power profile.

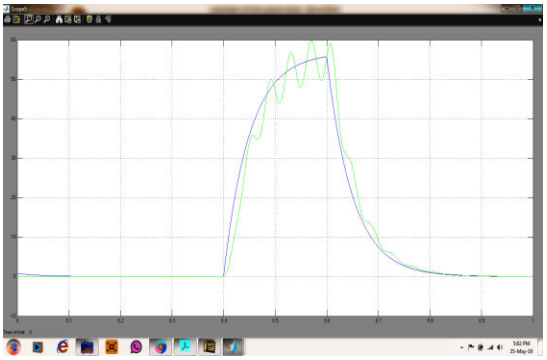


fig.6 The predicted PV power (Ppv_Ref) and the actualPV power (Ppv).

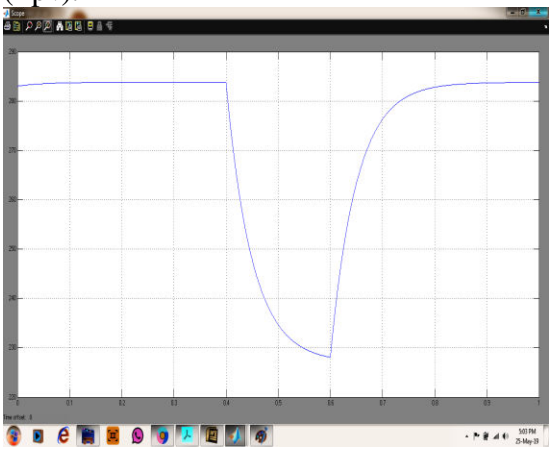


Fig7 The predicted demand-side active power (Pg_Ref) referencefor the PV-ES system.

The power profiles of the predicted and actual harvestedPV power (Ppv_Ref and Ppv) used in the simulation are plotted asshown in Fig. 6. The predicted profile of this PV power isforecasted using moving average method based on the data of the solar irradiance. Though the demandsidepower reference in practice can be predicted based onvarious information and objectives, a simple reference fordemonstration is calculated by the net amount of the demandsidepower. To highlight the power flowcontrol of the PV-ES with fluctuating PV power, Zcl and Znc aresimplified as constant during the simulation period. Hence, thePg_Ref according to shown in Fig.7. Such profiles arethen compressed into a period of 1 s for simulation.

CASE-B: PV-ES SYSTEM IN THE FIRST STAGE

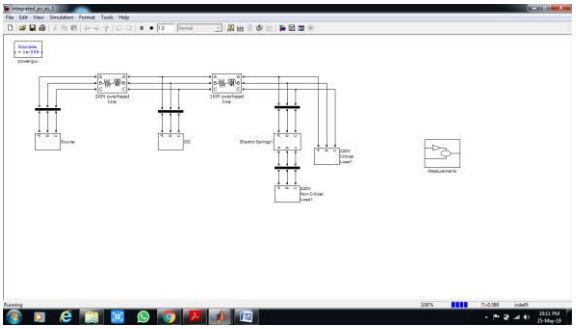
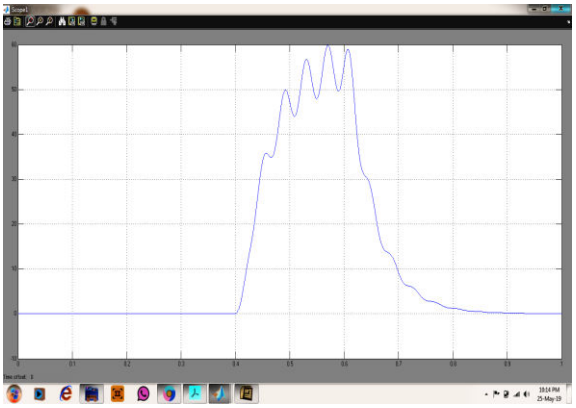


Fig:8. Simulation results of the PV-ES system in the first stage.



fig(a)

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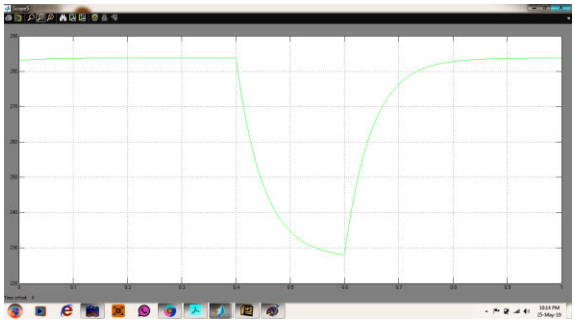
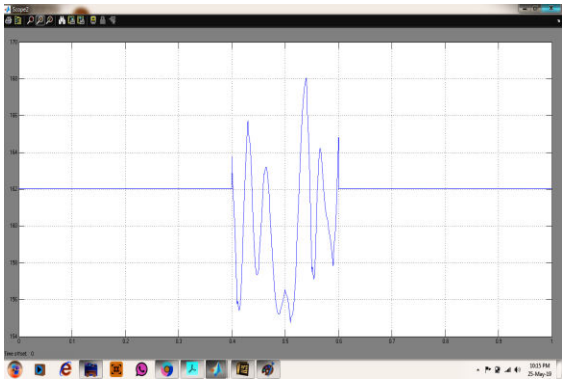
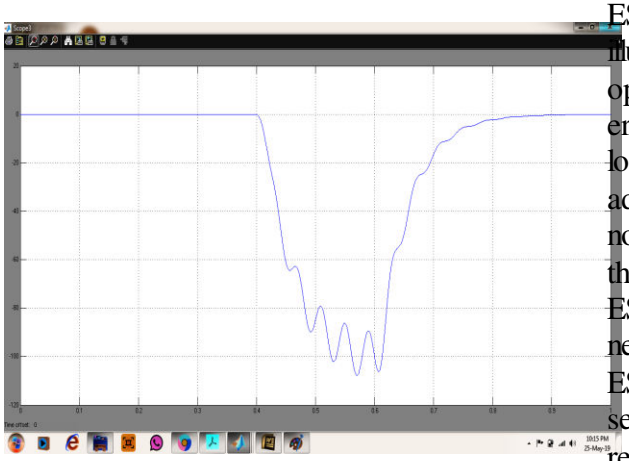


fig(b)



fig(c)



fig(d)

Fig:8.Simulation results of the PV-ES system in the first stage. (a) The activepower delivered by the ES (−Pes). (b) The predicted demand-side active power(Pg_Ref) and the actual demand-side active power (Pg). (c) The ES reactivepower (Qes). (d) The NC load power (Pnc).

The simulation results in the first stage are shown in Fig.8.The demand-side power is maintained at the nominal valuebetween the periods of t = 0 s to 0.4 s and t = 0.6 s to 1 s, whenthe PV-ES system is deactivated due to the absence of solarenergy. Figure 5.4a shows the time-varying profile of the activepower that is delivered to the power grid by the ES (−Pes).Considering the aforementioned assumption of a losslessconverter, the waveform of −Pes is exactly of the same shape asthat of the actual harvest PV power in Fig. 8a (indicated by thedotted line), which is as expected. In Fig. 8b, the predicteddemand-side active power reference (Pg_Ref) and the actualsimulated demand-side active power (Pg) are plotted togetherfor comparison. The results in Fig. 8b indicate that Pg can becontrolled by the PV-ES and it follows precisely the predictedreference.The active power consumption of the NC load in the PV-ESconfiguration is plotted in Fig. 8c to illustrate that the NC loadis indeed operating to compensate the prediction error of the PVpower. Clearly, the NC load power is adaptively adjustedclosely below and above the nominal power (160 W). Inaddition, the reactive power transferred by the ES is plotted asshown in Fig. 8d. The negative polarity shows that the ESreactive power is capacitive. By setting the reference of Pg_Ref,the reactive power of ES can be made either inductive orcapacitive. Here, wearbitrarily choose the capacitive reactive power.

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CASE-C: PV+BESS SYSTEM FOR COMPARISON

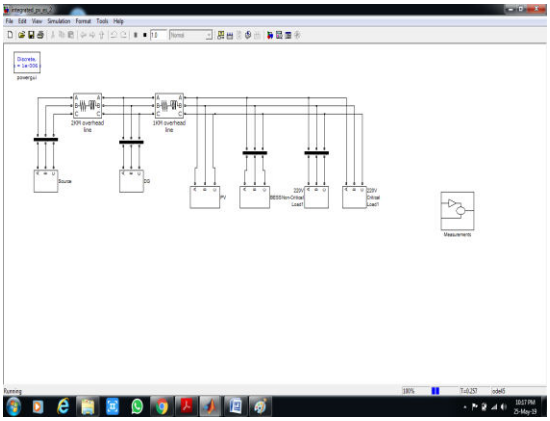
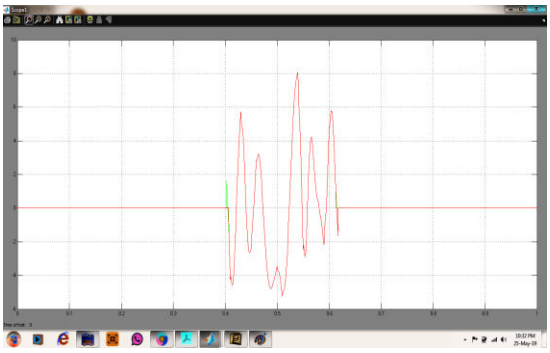
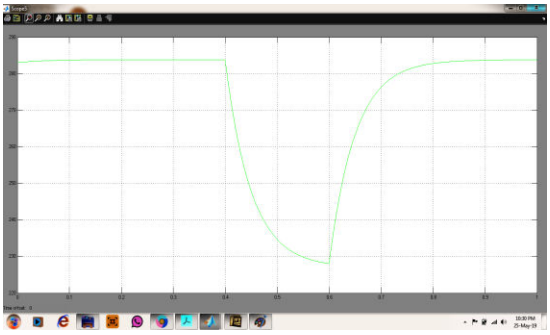


Fig:9. Simulation results of the PV+BESS system for comparison.



fig(a)

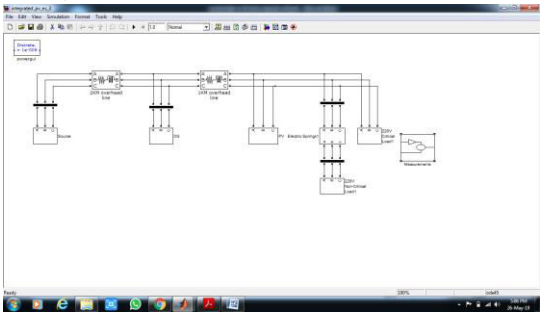


fig(b)

Fig:9. Simulation results of the PV+BESS system for comparison. (a) Theactive power delivered by the BESS. (b) The actual demand-side active powercontrolled by the PV+BESS systems.

In the second stage, to compare with the proposed PV-ESsystem, the conventional ESS and three existing ES systems assolutions for fluctuation issue of PV power are tested under thesame simulation configuration. In the conventional PV+BESS, which is capable ofcompensating the real power fluctuation by bi-directionalpower flow, is integrated with the PV inverter either via the DCbus or the PCC. The simulation results of the PV+BESS systemare shown in Fig. 9. As shown in Fig. 9a, the ESS directlycompensated the error between the predicted and the actual PVpower (depicted in Fig. 6a). Hence, the demand-side power iscontrolled precisely to follow the reference, as shown in Fig.5.6b. Although the solution of PV+BESS is straightforward andeffective in compensating power fluctuation, the installation ofBESS is costly. The estimated average cost of BESS installationfor commercial scale is $2,338 USD/kW. For instance, ifthe maximum prediction error is limited to ±20% of the nominalPV power, a PV system in the scale of 5 kW would requireadditional $2,338 USD for the installation of BESS, regardlessof future cost on the maintenance of batteries. In contrast, theproposed PV-ES system can save such a cost.

CASE-D: THREE TYPES OF ES SYSTEMS (ES-1, ES-2, AND ES-B2B) FOR COMPARISON



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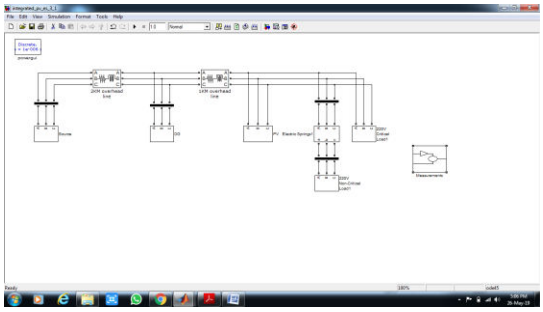


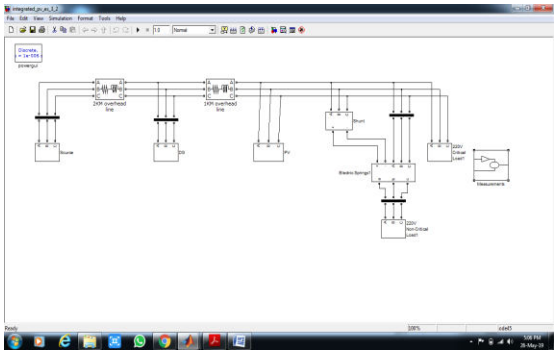
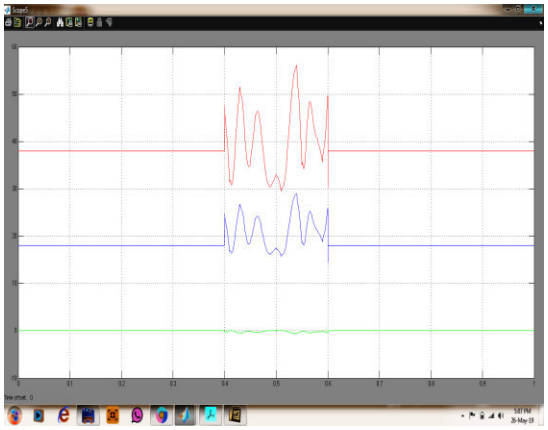
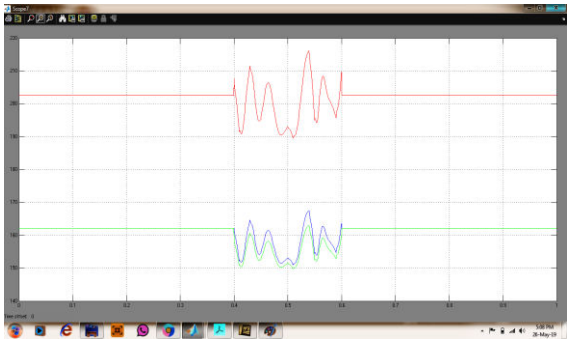


Fig:5.7. Simulation results of the three types of ES systems (ES-1, ES-2, and ES-B2B) for comparison.

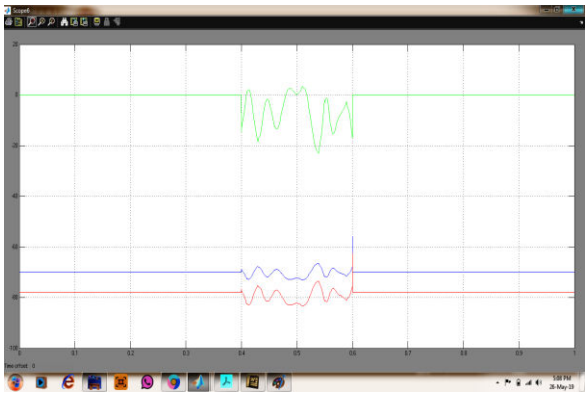


fig(a)

fig(b)



fig(c)



fig(d)

Fig:5.8. Simulation results of the three types of ES systems (ES-1, ES-2, andES-B2B) for comparison. (a) The active power delivered by the ES systems.(b) The actual demand-side active power controlled by the ES systems. (c) Thereactive power consumed by the ES systems. (d) The NC load power in the ESsystems.

For comparisons, the objectives of the other three ES systemsare set the same as the PV-ES system as a power balancer.Moreover, ES-2 and ES-B2B are preset to regulate the powerfactor of the smart loads at 0.9. This is a unique function of ES-2 and ES-B2B, which is in contrast to the proposed PV-ESsystem, since they can be configured to control the active andreactive power consumption simultaneously. Fig. 5.8 shows thesimulation results of three ES systems during the period. Asobserved from Fig. 5.8a, the active power

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delivered by ES-1 isalmost zero as it can only provide reactive compensation. Fig.5.8b shows the demand-side active power consumption underthe regulation of the ES systems. The profiles of ES-2 and ESB2Billustrates that both these ES are capable of tracking thereference as well as the PV-ES. However, the profile of ES-1contains obvious deviations, which is attributed to the limitationof ES-1. The reason is, with a purely resistive NC load, byproviding reactive power, the ES-1 can only decrease (but notincrease) the active power consumption of the smart load fromthe nominal value. Therefore, when the actual PV power ismore than the predicted value, the smart load associated withES-1 cannot consume additional power to compensate thedeviation. This is also confirmed by the corresponding NC loadconsumption and ES reactive power as indicated in Fig. 5.8c andFig. 5.8d, respectively. As a result, ES-1 cannot achieve thesame objective of the proposed PV-ES.Although ES-2 can provide (i) precise active powerconsumption control of the smart load as well as the PV-ES and(ii) controllable reactive power compensation which is betterthan the PV-ES, the operation requires real power from itsbattery storage. As shown in Fig. 5.8a, ES-2 requires around 38W for this 160-W NC load and the maximum-50-W PVgeneration. Additionally, as shown in Fig. 5.8c, the operation ofsmart load associated with ES-2 sacrifices the NC load severely.Here, the power of NC load is 198 W at the static state (forpower factor regulation) and reaches 224 W during the dynamicstate (for both the active power and power factor regulation). Inconclusion, while ES-2 can achieve the same objective as thatof the proposed PV-ES, this comes at the expense of a highercost and poorer performance of the NC load.By contrast, ES-B2B performs the best among the three ESsystems in the study. With the same precise active powercontrol of the smart load, the power delivered by the series partof ES-B2B, which is shown in Fig. 5.8a, comes from the griditself via the shunt ES. According to the power flow ofES-B2B in operation possesses a broader range and highereffectiveness in regulating the power consumption than that ofES-2. As depicted in Fig. 5.8a and Fig. 5.8d, the active/reactivepower through ES-B2B is smaller than that of ES-2. Also, thepower fluctuation of NC load is controlled at the same level asthat of PV-ES. In other words, ES-B2B performs as well as theproposed PV-ES as a power balancer.

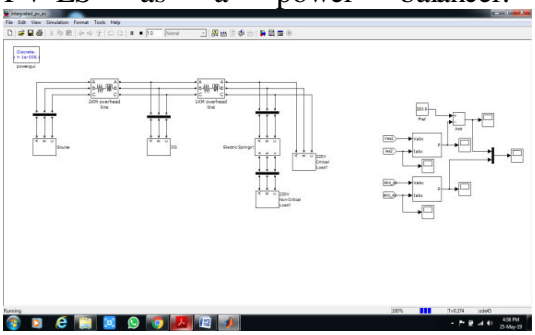

Fig:5.9. Proposed Simulation diagram of ES-PV power profile with fuzzy logic controller

Here we are discussed our proposed improvised control strategy compare the results with normal electrical spring i.e. is conventional electric spring with improvised electric spring..

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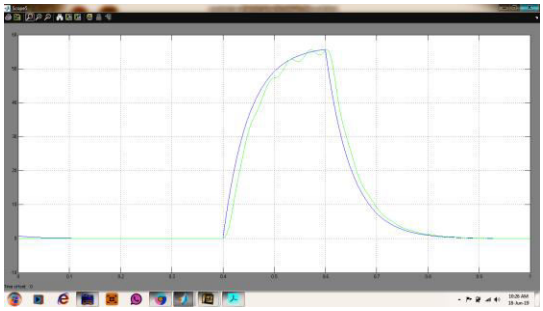
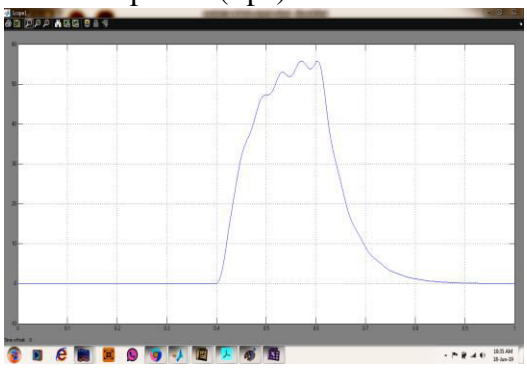
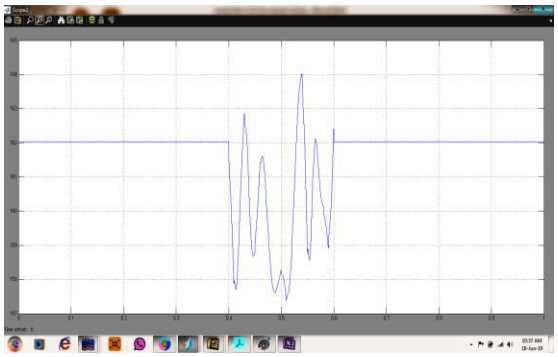


Fig:10. The power profiles of The predicted PV power (Ppv_Ref) and the actualPV power (Ppv).





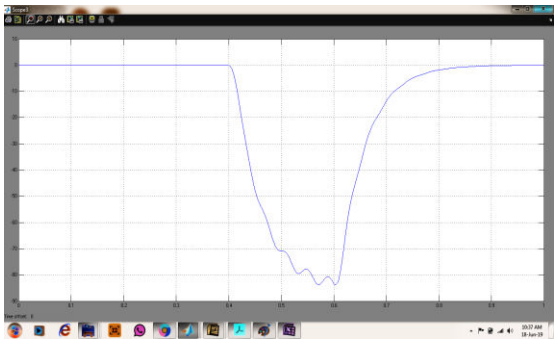
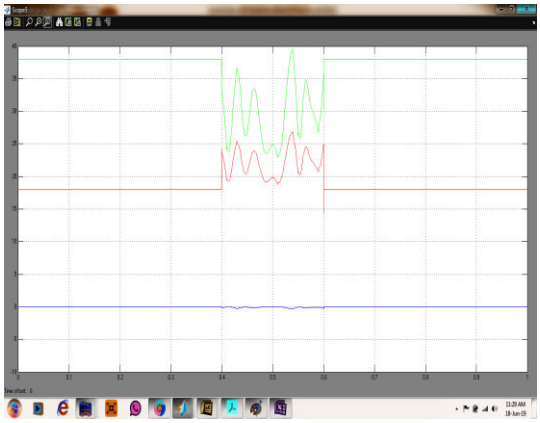
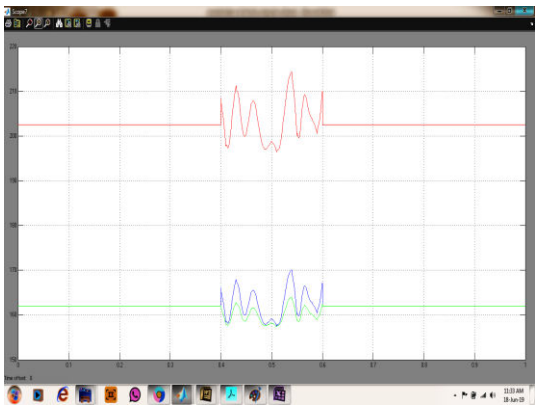


Fig:11Simulation results of the PV-ES system in the first stage. (a) The activepower delivered by the ES (−Pes). (b) The ES reactivepower (Qes). (c) The NC load power (Pnc).





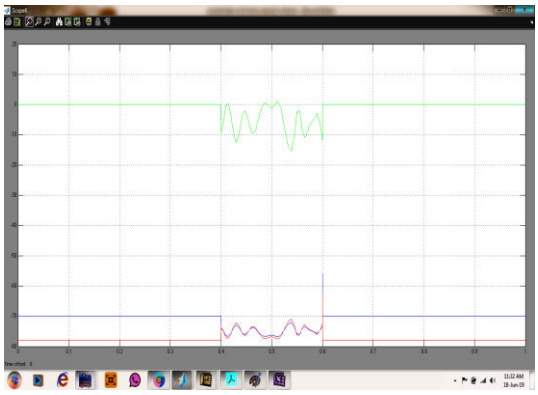


Fig:12 Simulation results of the three types of ES systems (ES-1, ES-2, andES-B2B) for comparison. (a) The active power delivered by the ES systems. (b) Thereactive power consumed by the ES systems. (c) The NC load power in the ESsystems.

However, theimplementation of fuzzy logic ES-B2B is much higher than that of PVES.While the proposed PV-ES provides a compactconfiguration including both the PV converter and

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the ESinverter, the ES-B2B system requires a back-to-back converter(combined with a shunt and a series ES converters), an isolationtransformer, and an individual PV inverter. To summarize, in terms of stabilizing the demand-side powerthat is influenced by the fluctuating PV power, the proposedPV-ES system performs as well as, if not better than, the otheroptions currently available. However, the low implementationcost of its converter circuit and its battery-free configurationmakes it much more competitive as a practical solution. Ifdeployed in a power system with existing ESS, dieselgenerators and load control strategies, the PV-ES will furtherbenefit the system: (i) PV-ES will be compatible with commonload control strategies as it provides continuous power flowadjustment as a smart load; (ii) PV-ES may help to reduce therequirement of the rating power of ESS and diesel generators,as it mitigates the power fluctuation of PV power.

CONCLUSION

In this project, a PV-ES system that is acting as a power balancer, is adopted in power distribution networks that have a high penetration of PV power generations, to assist in grid stabilization. The power flow analysis and implementation design in single-phase power system ensure that the proposed PV-ES can harvest the fluctuating MPPT PV power without involving battery storage, and adaptively control the active power consumption of the ES-associated smart load simultaneously. A comparison of the proposed PV-ES solution with the conventional BESS solution and those based on previous types of ES, validates that the former is a relatively better solution with a lower installation cost. Among proposed ES circuits, the ES-B2B should be the most prominent candidate in fulfilling this task, since the shunt and series inverters are both able to generate reactive power. The research can commence from the study of control technique with the use of a single ES-B2B and then escalate to the investigation of the joint performance of large-scale distributed ES-B2Bs. The application of fuzzy logic controller on the regulation of distributed ESs is a central approach which requires one-way communication for the broadcast of the control command to individual components. However, the difficulty lies on the derivation of a robust system model that can tolerate the plug-and-play feature of ES.

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