

“DESIGN AND IMPLEMENTATION OF OPTIMAL ELECTRIC SPRING FOR STABILITY AND VOLTAGE REGULATION IN DISTRIBUTION NETWORKS”

Mr. Deepa G.Singanapure
PG Student:

Department of EE engineering
Tulsiramji Gaikwad-Patil College of Engineering &
Technology, Nagpur

Ms. Vaishali Malekar
Assistant Professor

Department of EE engineering
Tulsiramji Gaikwad-Patil College of Engineering &
Technology, Nagpur

Abstract— The characteristics of distributed photovoltaic system power generation system is intermittent and instability. Under the weak grid conditions, when the active power of the PV system injected into the grid is fluctuant, the voltage of supply feeder will increase or decrease, thus affecting the normal use of sensitive load. The electric spring can transfer the energy injected into the supply feeder to the wide-voltage load, which is in series with the ES, to ensure the voltage stability of the sensitive load in the system. In this paper, a grid-connected photovoltaic simulation model with electric spring is built in Matlab / simulink. The voltage waveforms on the ES and sensitive load is obtained under the condition of changing the active power injected into the supply feeder by the grid-connected photovoltaic system. Through the analysis of the waveforms, we can find that the Electric spring is a kind of effective method to solve the voltage fluctuation of the supply feeder in the grid

Keywords: ES, GRID, Power Quality.

I. INTRODUCTION

Nowadays, our current-day environment is absolutely primarily based completely on the intake of electricity and on this case, there may be a heavy loss of powers at a few stage inside the height hours. Stability of strength in strength producing stations is one of the essential troubles within the modern-day fashion and it is very crucial to keep away from the shortage of power consumption Power device balance is an capability to regain synchronism on occurrence of disturbance. In extensive, an electric power system (EPS) is huge, complicated in nature, and interconnected and at risk of small sign oscillation on prevalence of disturbances. These low-frequency electromechanical oscillations (EMOs) persist due to inadequate damping torque due to immoderate/negative operating conditions. In the absence of sufficient damping, the EMOs can also persist for longer time ensuing in obstacles on electricity transfer capability of EPSs. In multimachine EPS model, distinct forms of EMOs are identified. The oscillations related to mills at a producing station, swinging with

understand to the relaxation of the strength system, are referred to as intra-vicinity mode oscillation In latest years, many optimization strategies based totally on random search are appropriate for fixing complex issues, which might be impossible to be solved with the resource of mathematical strategies along side the gradient. Application of new optimization techniques and fuzzy and realistic technique is the point of interest of researchers to layout a very good excellent controller for enhancement of small signal stability of a electricity machine The proportional important derivative (PID) kind PSS is used for boosting damping of EPSs . Many real worldwide manipulate systems typically music numerous control targets concurrently. At the on the spot, it's miles charming to satisfy all such desires exploitation the controllers with honest systems like as proportional-critical (PI) and proportional-vital-derivative (PID) that ar extraordinarily helpful in organization packages. Since in have a look at, those controllers ar normally tuned supported classical or trial-and-mistakes techniques, they may be incapable of getting right ever-converting performance to seize all style goals and specifications. This paper addresses a ultra-contemporary approach to bridge the gap among the potential of most reliable multiobjective management and PI/PID business controls. Preliminary the PI/PID control disadvantage is reduced to a static output comments control synthesis via the combined H_2/H_∞ manipulate method, and so the management parameters ar absolutely administrated exploitation Associate in Nursing reiterative linear matrix inequalities (ILMI) algorithmic rule. Numerical examples on load-frequency manage (LFC) and installation stabilizer (PSS) patterns are given perhaps the deliberate technique

.II Literature Review

1) Mohammadali Norouzi; Jamshid Aghaei ; Sasan proposed “Enhancing Distribution Network Indices Using Electric Spring under Renewable Generation Permission

IEEE Explore. March 2019 DOI: 10.1109/SEST.2019.8849120. The high penetration of renewable energy sources (RESs) has imposed new challenges in the operation of smart distribution networks. Changing the distribution networks indices is one of the untoward significant changes. In this paper, to improve the operational performance of smart distribution network, the application of electric spring (ES) as a new device in the power electronic revolution is proposed. Furthermore, the novel static model of the ES is presented and described in detail. In the next step, the effect of the presence of ES on distribution network indices in various scenarios has been studied. Finally, the suggested solution has been tested on 32-bus IEEE test microgrid as a distribution network by the GAMS software to analyze the potential and effectiveness of the ES in improving the microgrid indices. The results of the simulations verify the suggested solution completely by modifying the mentioned indices, and enhancing the conditions for the operation of the microgrid.

2) Yu Zheng ; David J. Hill ; Yue Song ; Junhua Zhao ; Shu Yuen Ron Hui investigated Optimal Electric Spring Allocation for Risk-Limiting Voltage Regulation in Distribution Systems," IEEE Transactions on Power Systems Volume: 35 , Issue: 1 , Jan. 2020 . This paper addresses the optimal allocation of the electric spring (ES) smart load device in radial distribution systems for voltage regulation. An ES can transform a connected noncritical load into a smart load providing voltage support and voltage suppression functions. A risk-limiting ES planning method is proposed to obtain the optimal ES configuration (number, locations, capacities, and types) to mitigate the voltage violations caused by uncertainties in renewable distributed generation. The forecasting uncertainties are placed into multi-state discrete levels to reduce scenario numbers. The voltage regulation capability of different types of ES are quantified and compared to determine the optimal allocation model. The optimal ES installation plan is identified as per the minimal total cost and lowest voltage violation risk. The proposed optimal allocation method is validated on a modified IEEE 15-bus distribution network.

3) Nikhil Sunil Janwe ; P. R. Jadhav proposed in "Grid Voltage Stabilisation by Electrical Springs IEEE Transactions on Power Systems (Volume: 35 , Issue: 3 , May 2020). proposes The extant scenario of the world reckoning the overconsumption of fossils and its disastrous impact on environment. But in contrary to the abundantly available source of energy their nature is intermittent and so the profile of the extracted power varies accordingly. Intermittent nature of renewable sources possess a threat to the grid voltage stability. Electrical Springs along with smart load

have recently being used as a smart technology in order to achieve stabilization of distribution networks in motive to shield the critical load against the fluctuations. This paper centered the problem statement of voltage control concomitantly clinch the effective demand side management through implementation of smart loads modeling. A simulation approach has been made for voltage study in the power system and an effective mean of distributed voltage control is demonstrated by capitalizing electrical springs. The power electronic circuit is being modulated and controller is set to achieve the requisite objective to extenuate the voltage fluctuation in the MATLAB/SIMULINK environment.

4) Daojun Zha ; Qingsong Wang ; Ming Cheng ; Fujin Deng ; Giuseppe Buja in Distributed Cooperative Control for Multiple DC Electric Springs with Novel Topologies Applied in DC Microgrid IEEE Xplore 25 March 2019 DOI: 10.1109/PEDG.2019.8807459 proposes DC electric spring (DCES) has been proposed for improving the power quality and voltage stability of DC microgrid. In this paper, a distributed cooperative control is applied for multiple DCESs with the recently proposed novel topology. The novel DCES is composed of DC/DC three port converter (TPC), bi-directional buck-boost converter (BBC) and battery system, while the BBC and battery system form the energy storage system of DCES. The distributed cooperative control for multiple DCESs, including the primary control and secondary control, is mainly used to realize the power allocation of multiple DCESs, local voltage stability and the consensus of DC-bus voltages and state-of-charges (SOCs) of battery among DCESs. The primary voltage control, including the phased-shift control, decoupling control and droop control, is used to regulate the local voltage of each DCES. The secondary control based on consensus algorithm, including control of DC-bus voltage and battery SOC, can regulate the DC-bus voltage reference and realize the SOC balance of batteries among DCESs

5) Yun Yang ; Yaxiao Qin ; Siew-Chong Tan ; Shu Yuen Ron Hui - in Reducing Distribution Power Loss of Islanded AC Microgrids Using Distributed Electric Springs With Predictive Control IEEE Transactions on Industrial Electronics (Volume: 67 , Issue: 10 , Oct. 2020) Recently proposed electric springs (ESs), as alternatives to conventional energy storage systems, are used to regulate bus voltages of ac microgrids with few or even no battery packs. Pioneering works have demonstrated the merits of ES in reducing the infrastructure and maintenance costs of expensive battery packs while still improving the power quality, stability, and dynamic responses of microgrids. However, distribution power loss reduction of islanded ac microgrids by controlling distributed ES has never been

investigated. The major novel contribution of this article is to extend the function of ES, along with emerging high-speed communication techniques, to enhance the rate of energy utilization in islanded ac microgrids. A predictive control in the power flow router calculates and feeds the optimal bus voltage references to each ES, which in turn controls the respective distribution power flow based on real-time power measurements. This allows the distributed ES to mitigate the overall distribution power loss of the islanded ac microgrid. Simulation results verified the significant power loss reductions in various structures of islanded ac microgrids with the distributed ES under the proposed predictive control. Experimental results also validate the effectiveness of the distributed ES operating under the predictive control in reducing the distribution power loss of a 3-bus and a 5-bus islanded ac microgrid.

6) Muhammad S. Javaid ; Adeel Sabir ; Mohammad A. Abido investigated in "Electric spring controller design for distribution network loaded by electric vehicles," *IET Energy Systems Integration* (Volume: 1 , Issue: 4 , 12 2019) This article focuses Although electric vehicles (EVs) offer a viable mean of commuting, their widespread penetration can have adverse effects on the current electrical distribution networks due to voltage drop and overloading of distribution transformers. In this work, a novel control scheme is proposed and implemented to support the voltage profile of a typical distribution network loaded by EVs. Electric spring (ES), a real/reactive power compensator, is driven by the proposed controller to provide voltage support under dynamic loading conditions. In the proposed scheme, the ES reference voltage is continuously determined and then compared with its instantaneous output voltage in a closed-loop configuration. The proposed controller is tested under various loading conditions both through simulations and digital implementation in the hardware-in-the-loop configuration to evaluate its overall performance. Results show that ES equipped with the proposed controller can be successfully used to fix the problem of the voltage drop caused by the sudden and simultaneous charging of EVs..

7) Diptargha Chakravorty ; Jinrui Guo ; Balarko Chaudhuri ; Shu Yuen Ron Hui, "Small Signal Stability Analysis of Distribution Networks With Electric Springs *IEEE Transactions on Smart Grid* (Volume: 10 , Issue: 2 , March 2019) This paper presents small signal stability analysis of distribution networks with electric springs (ESs) installed at the customer supply points. The focus is on ESs with reactive compensation only. Vector control of ES with reactive compensation is reported for the first time to ensure compatibility with the standard stability models of other components such as the

interface inverter of distributed generators (DGs). A linearized state-space model of the distribution network with multiple ESs is developed which is extendible to include inverter-interfaced DGs, energy storage, active loads, etc. The impact of distance of an ES from the substation, proximity between adjacent ESs and the R/X ratio of the network on the small signal stability of the system is analyzed and compared against the case with equivalent DG inverters. The collective operation of ESs is validated through simulation study on a standard distribution network.

8) . Zhiyu Zhao ; Keyou Wang ; Shihui Yang ; Guojie Li ; Yin Zhang discussed on Research on optimal operation of distribution network with electric springs *IEEE The Journal of Engineering* (Volume: 2019 , Issue: 16 , 3 2019) proposes The electric spring (ES) is a kind of electric device used for energy buffering, based on voltage and power management. ES transfers the voltage (or energy) fluctuation in the main bus to the non-critical load (NCL), stabilises the main voltage for critical load, and actively adjusts the power consumption of the NCL to achieve regulation goals of distribution network with wide voltage operational range of NCL. With lots of intermittent and fluctuating renewable energy resources into the energy Internet, the smart load integrated with the ES will play a greater role in the optimal operation of the distribution network. Here, the power flow optimal model of distribution network with the ES is proposed. Under different load levels, the flexible regulation of ES can reduce the overall voltage drop and optimise the operation of distribution network. The benefits of ES for the optimisation of distribution network are verified based on an improved IEEE 33-node case. Numerical results show that the ES relieves the voltage drop of the distribution network and improves the reliability of distribution network based on the interaction between the ES and NCL. The overall energy efficiency and reliability of the distribution network system are improved.

9). Mohamed Abdelaziz Ahmed ; Doaa Khalil Ibrahim ; Mahmoud Gilany Presented "Electric Spring Technology in Small Scale Residential Microgrid," *IEEE Xplore*: 11 July 2019 DOI: 10.1109/MEPCON47431.2019.9008166 Energy communities worldwide and in Egypt specifically encourage the household customers toward the renewable energy investment by utilizing grid-connected renewable generators (i.e. PV and wind turbines). Grid stability and power quality become the major concerns for the grid operators as they are too much affected during the increasing penetration of distributed renewable generators and also the growth of non-linear loads at end users. Electric spring (ES) technology is recently applied as distributed voltage controllers intended to stabilize the electrical grid in the presence of

the distributed generators and the non-linear loads of the consumers. Consumers' satisfaction towards the grid stability is very essential as most of the household applications include sensitive loads that require a clean power with definite voltage value. This paper analyzes and verifies the electric spring technology in a household application with a renewable energy investment through a grid-connected PV panel, while a standby diesel generator operates in case of utility failure. The proportional-integral (PI) controller of ES has been successfully optimized using a genetic algorithm. A developed MATLAB/SIMULINK model is tested under a real household loading curve, typical PV generation profile in sunny/cloudy days, dynamic response of the standby diesel generator, and the utility disturbances (i.e. voltage decrease, increase, and fluctuation). For all aforementioned tested disturbances, the ES has succeeded to stabilize the voltage for the household sensitive appliances (e.g. computers, TV, washing machine, etc.).

10) Tianbo Yang ; Kwan-Tat Mok ; Siu-Shing Ho ; Siew-Chong Tan 2019 Use of Integrated Photovoltaic-Electric Spring System as a Power Balancer in Power Distribution Networks IEEE Transactions on Power Electronics (Volume: 34 , Issue: 6 , June 2019 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..

III CONCEPT

In the proposed the actual circuit and set of rules implementation of an ES to modify the AC mains voltage through reactive electricity reimbursement call for aspect control technique to deliver voltage and strength regulation.

To reduce the usage of strength garage equipment within the destiny smart grid with sizable renewable electricity resources can be found out through ESs Voltage regulation in a microgrid by more than one electric powered springs based totally at the disbursed control is provided in, that can lessen the cost of centralized control and compensate the inaccuracy of the traditional droop manipulate efficiently. Thus, the jury-rigged management scheme opens new avenues for utilization of the electric spring to a larger volume by using presenting voltage and electricity stability and improving the power best in the renewable strength hopped-up microgrids. An ES is an electric device which is similar to a mechanical spring and may be used to i) keep electric powered energy; ii) provide power help; and iii) damp strength oscillations. When a mechanical spring is stretched or compressed, it exerts a force proportional to its alternate in displacement. Potential strength is saved within the mechanical spring when the duration of the spring deviates from its herbal length In a distribution device, with numerous inductive and capacitive loads, a widespread reactive electricity injection can worsen the electricity component of gadget and lead to decreased performance.

Thus, a function of energy element correction may be integrated inside the ES along with present characteristics of voltage and energy law t became also shown that the improvised manipulate scheme has advantage over the conventional ES with handiest reactive electricity injection. Also, it's far proposed that electric spring may be embedded in destiny home appliances. If many non-critical hundreds within the buildings are prepared with ES, they may provide a dependable and powerful approach to voltage and power stability and electricity aspect correction in a renewable electricity powered micro-grids. It would be a completely unique call for aspect management(D S M) answer which may be applied with none reliance on data and conversation technology

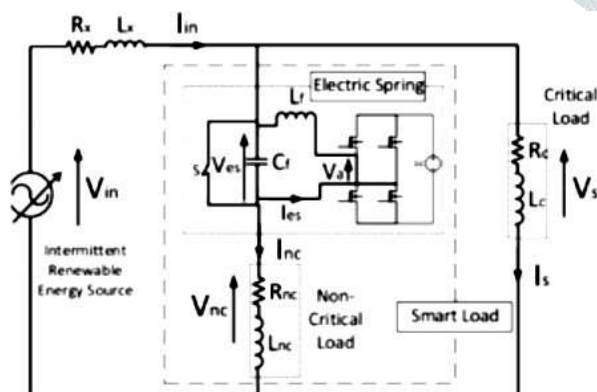
IV OBJECTIVES

The electric spring (ES) is a modern-day tool that has emerged as a possible opportunity for fixing issues related to voltage and energy balance in disbursed technology-primarily based smart grids (SG). In order to take a look at the combination of ESs into the electric community, the constant-nation simulation fashions were advanced as an vital tool. Typically, those fashions require an equivalent electrical circuit of the in-test networks, which means including restrictions for its implementation in simulation software. These restrictions generate simplified fashions, proscribing their application to particular situations, which, in a few instances, do no longer completely practice to the

wishes of cutting-edge energy systems. Therefore, a strong steady-kingdom model for the ES is proposed in this paintings to effectively represent the strength trade of multiples ESs in radial micro-grids (μ Gs) and renewable power assets no matter their bodily region and with out the want of additional regulations. For solving and controlling the model simulation, a changed backward–ahead sweep technique (MBFSM) is applied. In evaluation, the voltage manage determines the working situations of the ESs from the constant-kingdom answer and the reference voltages established for every ES

- The objective of the proposed work is to conserve power by making the non-critical loads draw less power during generation uncertainties
- The power protection system would disconnect the microgrid from the grid, when the power consumption of the microgrid is higher than the generated power of the grid
- The critical load is connected in shunt with this smart load whose voltage to be maintained constant. Depending on the type of Critical Load, the phase angle between the current of Non Critical Load and ES voltage is controlled to maintain constant bus voltage..
- The voltage across Critical Load is maintained constant by activating ES and injecting a voltage in series with the Non Critical Load

IV PROTOTYPE



. Fig 4. Circuit diagram of Electric Spring

The concept of Electric Spring was introduced by

drawing parallels to a traditional mechanical spring . In a weakly regulated grid, it could be realized through an inverter and is attached in series with non-critical load, such as air conditioners, as shown in Fig. 1, to form a smart load. In parallel to this smart load, critical loads like a building's security system are connected. As a result, the non-critical load voltage and power vary dynamically in accordance to the fluctuations in the weakly regulated grid due to intermittent renewable energy power. In order to provide only reactive power compensation from electric spring, the compensation voltage, V_{es} should be perpendicular to non-critical load current, I_o The electric spring voltage is governed by:

$$V_s = V_0 + V_{es}$$

V Research Methodology/Planning of Work

In the proposed been used for providing voltage and power stability in a weakly regulated/stand-alone renewable energy source powered grid. It has been proposed as a demand side management technique to provide voltage and power regulation. To improve voltage regulations, stability and power factor in ac transmission and distribution systems and how the reactive power affects power system operations, the challenges to voltage control in power systems and to provide background information on the mathematical challenges associated with voltage control and reactive power supplied. This paper presents an energy efficiency comparison of the electromagnetic and electronic ballast systems under both full power and dimming conditions. for controlling the output from individual DG's that were installed in micro grid the author developed an energy control system because as we know that DG's uses an renewable energy sources have an unstable output and this can negatively affect existing electric power system. To control the active power supplied by distributed generation system while compensating harmonics and reactive currents caused by nonlinear loads using shunt active power filter. The earlier technology shows that the traditional series reactive power compensators use output voltage control for a reactive power controller, but the proposed technology demonstrate characteristics different(input voltage control) from traditional devices such as series reactive power controller.

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