International Journal of Advance and Innovative Research
Volume 9, Issue 4 October - December 2022
ISSN 2394 - 7780

EPITOMIZE OF ELECTRIC SPRING FOR IMPROVEMENT OF POWER QUALITY FOR DEMAND SIDE MANAGEMENT

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ABSTRACT
A susceptible renewable energy source powered system originally used Electric Spring (ES), a revolutionary smart grid technology, to provide voltage and power stability. Voltage and power control has been suggested as a demand side management strategy. The deployment of an electric spring in connection with non-critical building loads, such as electric heaters, freezers, and central air conditioning systems. In this paper, a review has been done for electric spring. The current characteristics of the electric spring of voltage and power stability, a control scheme would be able to provide power factor correction of the system, voltage support, and power balancing for the key loads, such as the building's security system.

Keywords: Electric spring, power quality, critical load, load demand

1. INTRODUCTION
Only a limited number of countries, including India, have committed to raising the penetration of renewable energy sources to 20% [1-3] by 2020. Increased usage of these renewable energy sources in the main grid or distribution systems results in major stability problems [4-6], thus it must be handled delicately. Due to the unpredictable and intermittent nature of renewable energy sources, load management strategies rather than generation management are the only way to address stability challenges. One such option is demand side management (DSM), often known as demand dispatch. Various DSM techniques have been researched over the last three decades. All of these demand side management strategies either use a peak load reduction strategy. Figure 1 present the demand side management.

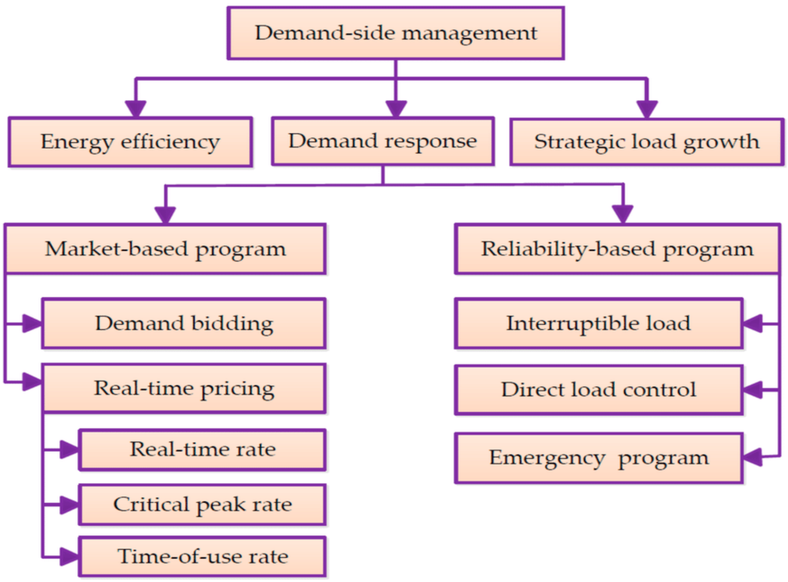

Figure 1: demand side management

Analogy between mechanical springs and ES [22] that incorporate various types of energy storage. One or more of these techniques, such as real-time pricing [10–12], scheduling [13– 15], or on-off control [16–17], of delay-tolerant loads, such as washing machines, provides Demand Side Management through load shaving. The most effective form of demand side management [18] for balancing load demand is battery storage, although it is quite expensive and has a short lifespan. The same waste's disposal is once again having major environmental problems. Only certain forms of information and communication technologies can be used to achieve all these Demand Side Management techniques (ICT). Another such technique for managing electrical loads remotely and intelligently depending on a certain tariff circumstance, or when the system's power requirements are very low, is the Internet of Things (IoT) [19]. All of these technologies have an additional cost to be paid in terms of signal traversal latency and hacker risk. It is somewhat intrusive in nature and restricts the end user's ability to use energy freely on a real-time basis.

ISSN 2394 - 7780

According to the needs of the load, an electric spring is a custom power device, or power electronic converter, that is coupled in series with noncritical loads and operates with input feedback and output voltage control [20].

2. Generation of Electric Spring

A voltage source controlled by current can alternatively be thought of as an electric spring. According to the source of DC voltage present at the DC bus, electric springs can be categorized as follows:

1) 1st generation electric spring
2) 2nd generation electric spring: A battery is connected on DC bus [25].
3) 3rd generation electric spring: A bidirectional power electronic converter of appropriate type and of an appropriate configuration is connected on DC bus [25].

The first generation of electric springs is made up of a capacitor that is wired to a DC bus [21].Electric springs of this generation can only feed in or absorb reactive power and can function in any of the two modes listed below: inductive or negatively resistive. By suppressing line voltage, the inductive mode absorbs reactive power. By regulating the injected voltage over a range of 0° to 360°, an electric spring can source or sink both active and reactive power. On the other hand, the electric spring is sourcing actual power while it is in the negatively resistivephase. When the load current and the electric spring injecting the voltage are in quadrature, thecontrol of these electric springs can be designed to source or sink just reactive power at that angle, while handling both active and reactive power at any other angle. The noncritical load'svoltage and, consequently, its power flow are altered by the injection of voltage by an electric spring. The voltage that is available across the critical load is obtained by adding the voltages of the ES and noncritical loads algebraically. By varying the power of noncritical load, the voltage profile of critical load is kept constant and the grid is given voltage stability [22]. It isaccomplishing this in a way that is comparable to a mechanical spring, thus living up to its name, and in line with demand side management needs in order to achieve risk-limiting dispatch [23,24].

3. Compensation of Electric Spring

The whole mathematical model is derived in detail, together with a comprehensive ES steady-state analysis for various real and reactive power compensations. Various typical loads that arepartially or entirely mitigated by ES are discussed. A numerical example at the conclusion demonstrates how the ES is operated to accomplish a specific range of power sharing for compensatory reasons between the ES and the grid for various loads.

4. Basic working Principles of Electric Spring

In many contexts, ES functions similarly like a mechanical spring. While electric springs striveto sustain voltage, dampen electrical oscillations, and also have the ability to store electrical energy, mechanical springs are primarily employed to offer a mechanical support, store energy, and dampen mechanical oscillations. We can see how the equations for mechanical andelectrical springs are similar. The following force is applied to the actual mechanical spring:

$$F = -k * x \quad (1)$$

Where: ' k ' represents the spring constant and' 'is the displacement. While for the electricspring,

$$q = -C * V_{es} \quad (2)$$

Where: ' q ' is the charge stored in the capacitor with capacitance 'C ' and 'V_{es} ' is the voltage atthe terminal of the electric spring.

There is also similarity in stored energy equation where the energy stored in the mechanicalspring is:

$$E = \frac{1}{2} * k * x^2 \quad (3)$$

Where: ' E ' is the amount of energy stored, 'k ' is the material constant and ' x' is thedisplacement. While in the electric spring the energy stored is:

$$E = \frac{1}{2} * C * V_{es}^2 \quad (4)$$

ISSN 2394 - 7780

Where "V" stands for the terminal voltage and "C" stands for capacitance. According to the spring position, there are typically three scenarios for the mechanical spring: When no force isapplied to the mechanical spring, it is in the neutral position, compressed position, and extendedposition. Similar to how three different ES processes can be compared to the mechanical springsituations shown in Figure 2.

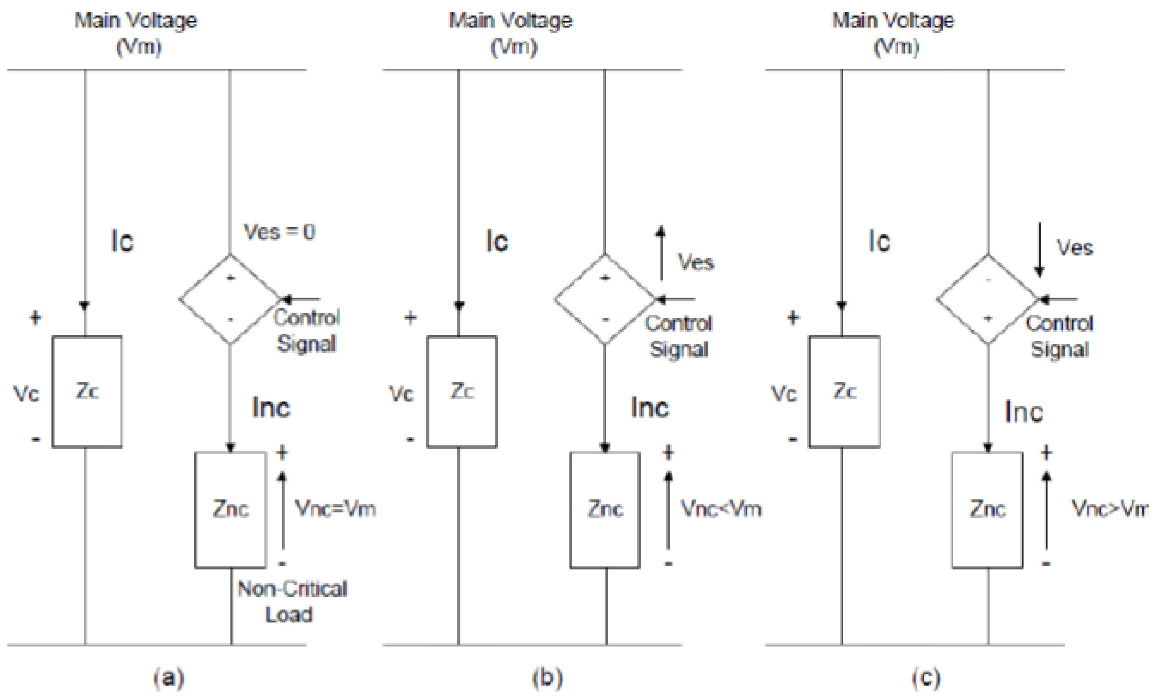

Figure 2: ES in three different phase (a) Neutral mode (2) inductive mode (3) capacitive mode

Where

Z_c & Z_{nc}: critical and non-critical loads respectively.

V_m: main voltage of the load bus.

V_{es}: voltage at the electric spring terminals.

V_C & V_{nc}: voltage of critical and non-critical loads respectively.

I_c & I_{NC}: current of critical and non-critical loads respectively.

There are two basic kinds of loads: essential loads, in which the voltage and power utilizationmust persist, and non-critical loads, in which the voltage may fluctuate within a specific rangeand consequently influence the non-critical load's power consumption. A novel combination of smart load, such as household appliances, is created by connecting an electric spring in serieswith non-critical load.

The electric spring in Figure 2 can be viewed as a source of controlled voltage. The mechanicalspring's neutral state situation suggests that there is no applied force at all. As shown in Figure2, the neutral position of ES indicates that its voltage, "V es," is zero and that the main voltage,

"V m," is at its nominal value (a). This indicates that the necessary amount of power is providedby renewable energy sources.

In the second scenario depicted in Figure 2 (b), the generated power is insufficient to cover theload since the main voltage is lower than the nominal value. The electric spring functions as avoltage booster in the capacitive mode to maintain the mains voltage at its nominal level and reduce the applied voltage across the connected non-critical load in series to use less actual power.

When the generated power exceeds the load demand in the third scenario depicted in Figure 2

(c) and the main voltage exceeds its nominal value, it is required to reduce the main voltage toits nominal value. In this instance, the electric spring performs an inductive mode voltage reduction function. The voltage of the in-series linked non-critical load is reduced, and as a result, the real power consumed is likewise reduced. When the resistive load is integrated in series with the ES, this voltage reduction of the non-critical load in capacitive mode is viewedas a constraint. When the ES runs in capacitive mode or inductive mode if the non-critical loadis inductive, the voltage of the non-critical load is increased. The electric spring's inductive and capacitive modes are two variations on the mechanical spring that can modify the displacement in either direction when a mechanical force is applied. According to the requirements of the device, non-critical load voltage may be increased or decreased within a defined range. The convenience of the user shouldn't be impacted by this variation.

CONCLUSION

By evaluating the available literature in this field, this paper discusses the theory,modelling, implementations, and restraints of an electric spring (ES). A specialised power device known as an ES (power electronic converter) is progressively becoming a prominent component of the smart grid. It is thought to be working under the impact of erratic, intermittentrenewable energy sources and offers stability to the grid by managing actual and reactive powerto renewable energy sources. Since ES is connected between the grid and the load, it can dampen the grid's oscillations. Based on the range of acceptable voltages, loads are divided. Itsomewhat corresponds to the demands of demand side management, and that too on a real-timebasis. Review of the modelling, analysis, and control characteristics of electric springs.

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