A Review of the Recent Approaches to Gear Photovoltaic Systems Towards the Most Optimum Operation

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Abstract

In this paper, a review of renewable energy researches over the last ten years about all types of renewable energies is presented. As for the exceptional merits of solar energy, the paper focuses on how energy pursuers can maximize their benefits from it. It also provides thorough discussion on multiple researches and talks that handle different types of AC and DC circuits, schemes and control algorithms used in the renewable energy domain. The study explores different modules; key among them are: nonlinear loads, power generation units, neural network algorithms to obtain the maximum power generation, power exchange controllers, system stabilizers, Power quality improvement tools. The paper focuses on the features and characteristics of electric springs and their roles in maintiang stable operation of standalone (islanded) microgrids.

***Index Terms*—Photovoltaics, Fuel Cells, Load management, Antlion algorithm, MPPT, utility level batteries, DC-DC boost converters.**

I. Introduction

The importance of new and renewable energies emerged through painstaking efforts of scientists after the political oil crises in the second half of the last century. The available energies of coal and oil (fossil fuels) are non-sustainable and have environmental concerns. The generated energies were consumed in the operation of machines, lighting and the operation of different means of transport. After making sure that coal and oil are out of the way, scientists have made available forms of energy such as solar, wind, waves, biogas and others. Renewable energy is Therefore it is considered one of the most important sources of energy in the future. Various studies and field demonstrations are underway. After the direct direction to produce energy from the sun , wind and other forms after it was in the laboratories of research and exit to the circulation and the production of electricity with a capacity that allows to solve the traditional energy. Some problems were happened. These problems are the frequency in the strength of the source, such as the absence of the sun, the appearance of clouds in the sky and the weakness of wind power, which led to the oscillation of power generation between weakness and strength .
The researchers have led to improve the performance of the equipment to connection with the public networks, taking into account the compatibility between public networks and new network equipment in a secure manner. There are many types of

control of these generation plants for new energies according to the equipment of energy consumption, including the use of AC or DC power according to request of energy. Control has become a necessity in performance, using traditional control equipment or innovative equipment to improve its performance. Therefore, researches has varied according to the needed power or according to the load and the energy generated to maintain the equipment as well as the consumables to obtain safe operation. For years, researchers have been working hard to discover different types of equipment needed to improve the performance of an energy-generating system. However, the nature of the distribution system has changed today, and energy officials play an important role in improving performance of any distribution networks
In view of the wide scope of work in the new and renewable energies, in this research, we refer to solar energy to know the forms and methods of control of the energy generated by each unit's energy and type of control, classification of these methods and the latest methods of control. The photovoltaic units which are concerned with the classification in this present work only.

II. Components, Technologies, and Algorithms of PV systems.

To conduct a review study to reach the set of studies published in the last few years, to know the trends of the research and the results achieved, to obtain the points of development and modernization in the direction of the research and the results to be taken into consideration in actual application. Recent research has been found to be divided into two main sections as mentioned in the following:

1- Researches that is directed to the generation systems and control by the equipment control which how to get the safe connection to other types of generation systems and compatibility between them.
2- Researches aimed to the independent generating systems without contact with the other systems of generation with its control systems to ensure the safe operation.
3- Researches that concerned with units equipped with power quality improvement to kept the generating units in the save use like smart impedance , electrical springs and multifunction.

The research, which was reviewed in the period from 2010 to 2018 only, indicates a major development in the field of solar energy, which leads to the rapid application in the working life. In the last period and in the second decade of the twenty-first century there is a steady increase in the amount of research and with the progress of time in this period, which was taken into consideration between a few studies at the beginning of the period to a large number in the recent period.

With the change in the number of studies provided with the number of units that are powered by solar energy with an increase in the generated energies that amount to several million units of power, but this indicates that the amount of power generation from solar energy specifically works to replace fossil fuel stations and nuclear fuel.

It has been reviewed a number of published researches in photovoltaic power source only for that period, which nearly 100 published research. It's found that more than a quarter of this group is studying the systems of generation and control by DC Converter and in the case of the consumption in the alternating it used the inverter to feed the consumer or public net with alternating current.

The increase in consumption of solar energy in the recent period indicates that this field is fertile field and worthy of study and encourage research work to reach the maximum possible generation of energy. With the change in the power generation, the use of spring that works on the load stability when connected to the network, it helps to stabilize the work in the unit.

With the study of solar generating systems and how to control them and study the amount of faults and loads, the spring is used, which stores electrical energy in the case of lack of load source of solar energy.

The generations of photovoltaic units are having several classifications:-

- Grid connected PV (with) and (without battery).
- Off grid PV system (for house and industrial)/ (with battery).
- Hybrid PV generation system (wind+PV hybrid system)/(PV+ diesel hybrid system).
- PV units based utilities (solar lamp /solar mobile charge, ets).

As the photovoltaic generating systems researches are also classified as unit works according to get the maximum power point tracking MPPT.

1- Unit works according to obtain the maximum power point tracking MPPT.
2- Nonlinear load power generation units.
3- Generating units working under Neural Network to obtain the maximum power generation.
4- Units working with the use of devices to stabilize the amount of energy generated.
5- Power quality improvement with Electrical Spring (ES).

All of the research which are published and obtained in all fields will be reviewed before mentioning the production of energy photovoltaic power.

A. Unit works according to obtain the maximum power point tracking MPPT

They introduced a study concerning with the nonlinear characteristics of the PV module need special techniques to produce maximum power. The techniques used for tracing the MPPT from the nonlinear current-Voltage characteristics through power electronic circuits. They proposed a technique to removes the limitations rapid changing in the environmental form. To improve the efficiency and decreases the oscillation power loss under steady states. It is also designed with a combination of

additional variable size conductivity with FSCC technology. Initially, the FSCC forces the PV system to work near MPP and then the Inc. technique track the exact peak. Matlab/Simulink software was used to implement the proposed hybrid technique. Finally, the results verify its Agreed performance max. power curve as shown in Fig.1. [1].

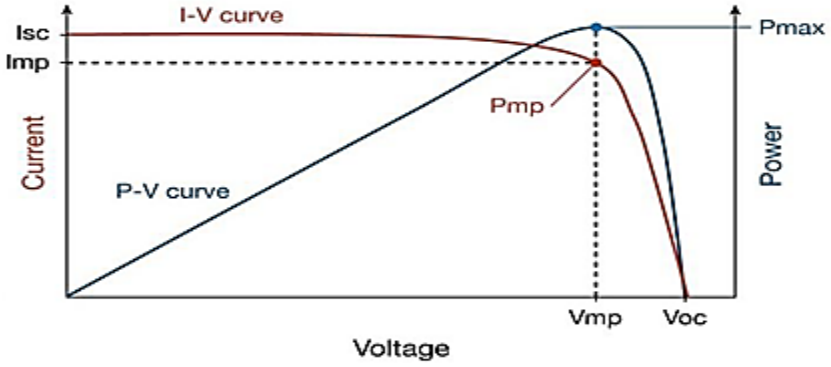

Fig. 1. I-V and MPPT curves of PV cells.

As shown in Fig.2 A new control system was applied in the direct (SMC) mode on a three-phase network connected to the PV system. They suggest a loop control using the MPPT algorithm control to improve the system efficiency and its performance. They results showed very fast dynamic response (a few milliseconds), and low steady states error (below 1%), and low current (2.14%) [2].

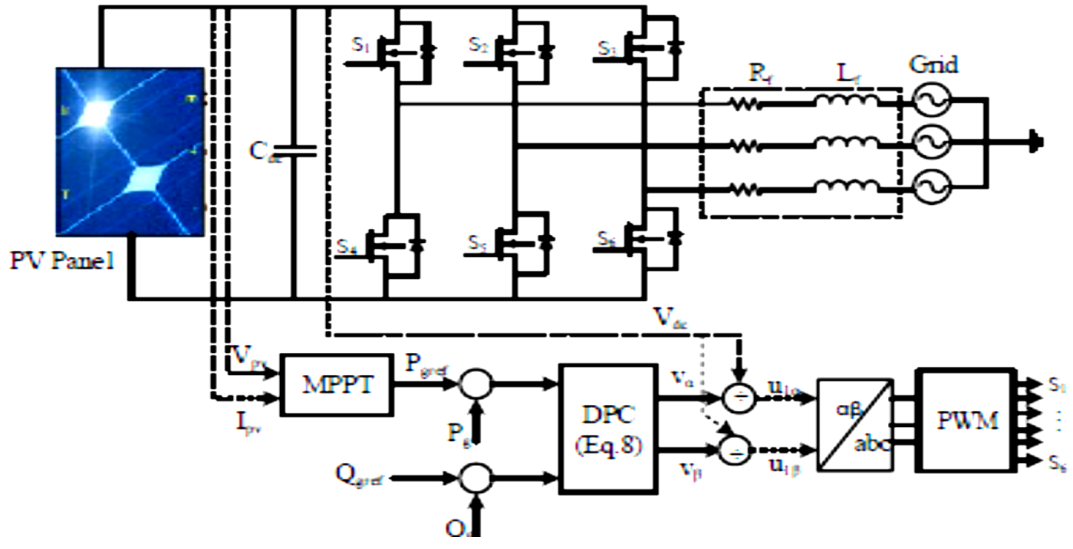

Fig. 2. The system studied in [2].

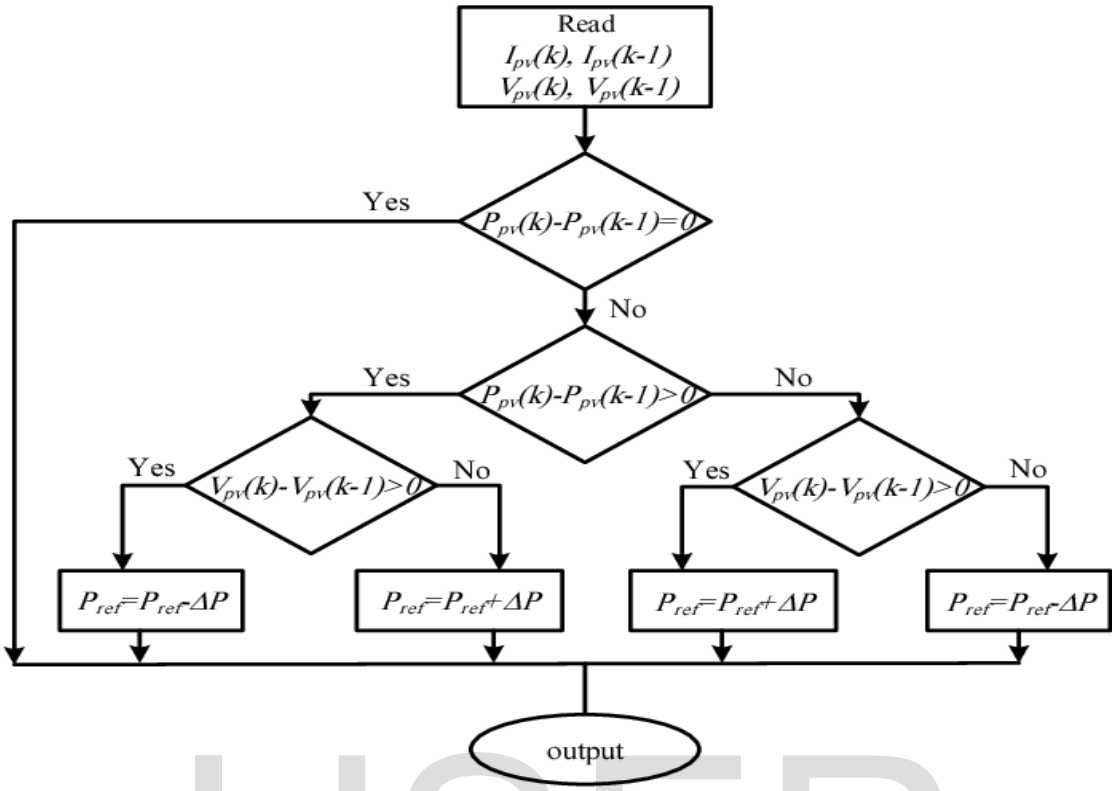

Fig. 3. Flowchart of MPPT algorithm with Pref output [2].

In Figs [3-10] explained the group of researches was introduced the same manner of using the MPPT technique to get the maximum power of their systems. They also applied their suggested electronic circuits to improve their systems efficiencies and its performances.

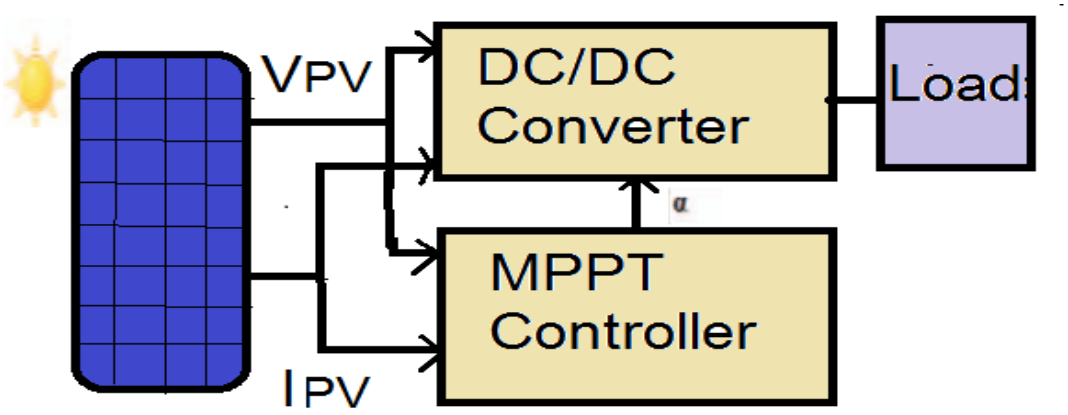

Fig. 4. A model of PV cell configuration to have photovoltaic cells as a current sources feeding in parallel [3].

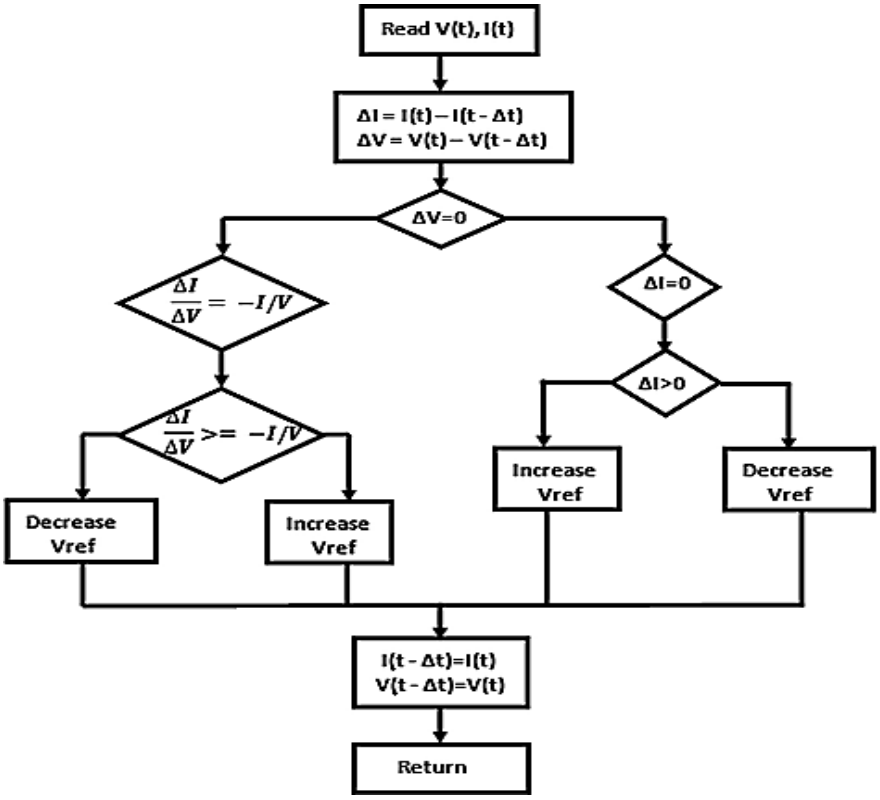

Fig. 5. The incremental conductance diagram [3].

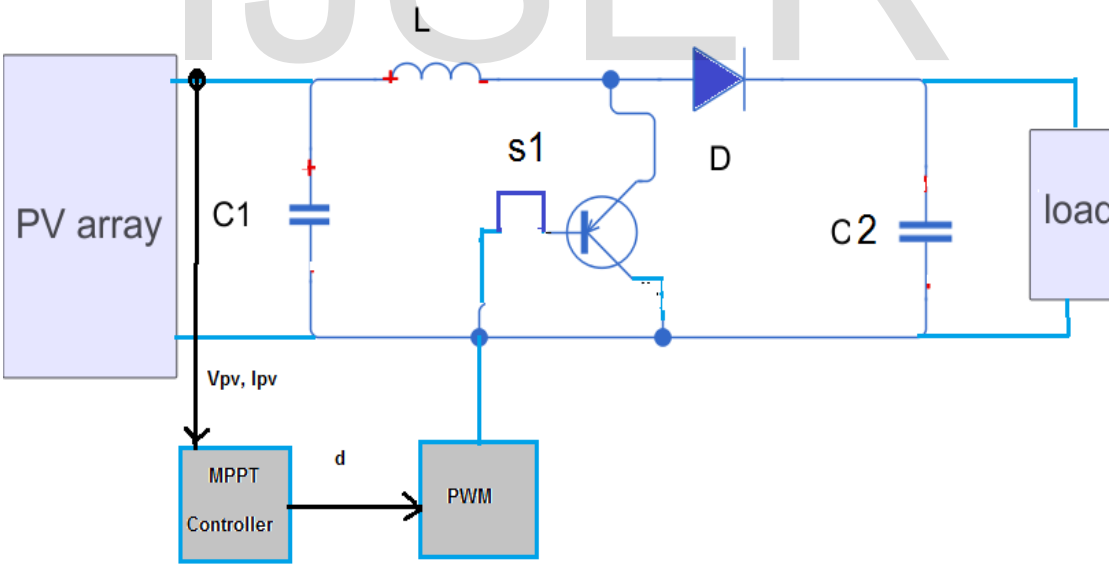

Fig. 6. Typical photovoltaic system [4].

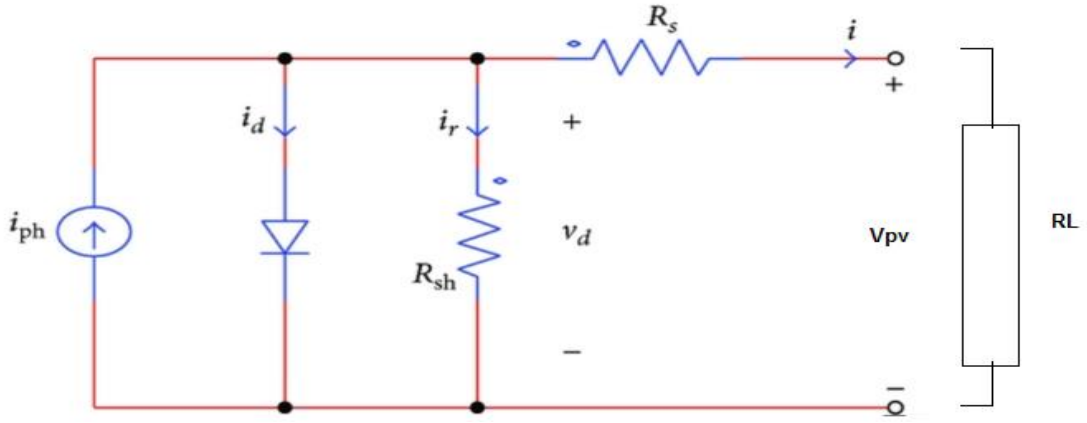

Fig. 7. Photovoltaic cell equivalent circuit [5].

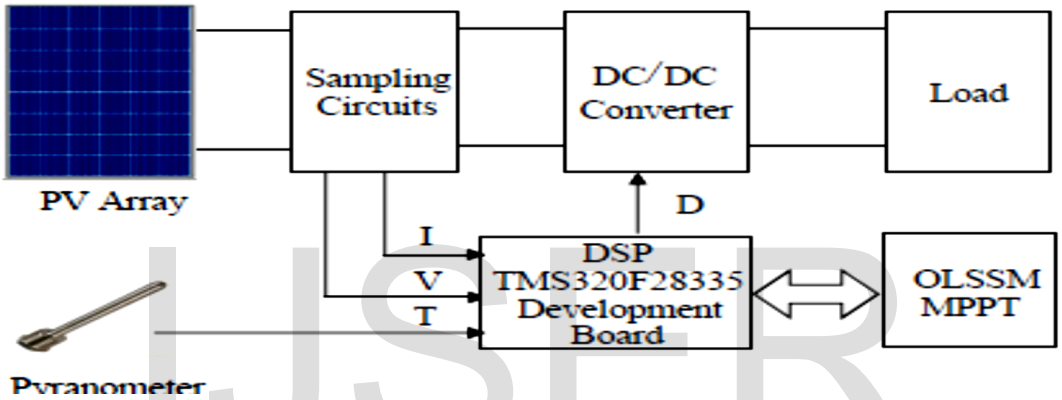

Fig .8 .Block diagram of their experimental set-up[6].

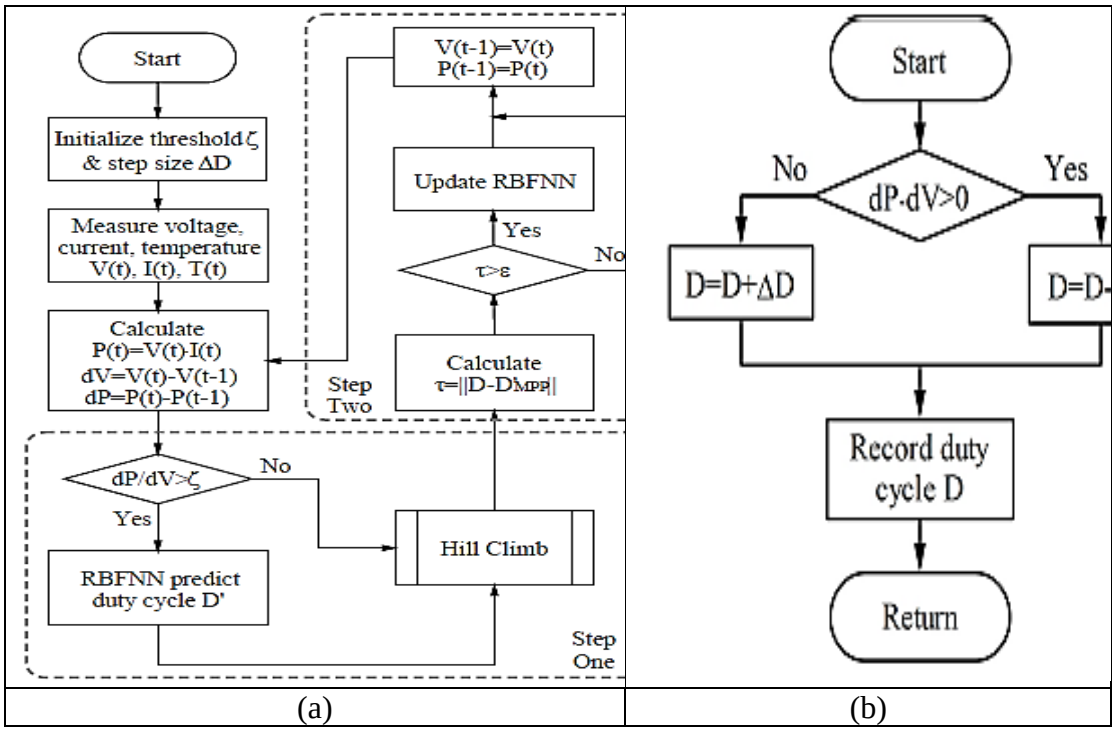

Fig.9 . Flowchart of the proposed OLSSM based MPPT method (a) Main program, (b) Hill climb.[6]

In [7] for the distributed MPPT phase, interoperability topologies are used to effectively reduce input and output perturbations without the need for additional components. As for the central ascension phase, some narrow control switch topology was used, with the modules being formed as a structure for the parallel input chain**.** Fig [10] Shows the proposed system.

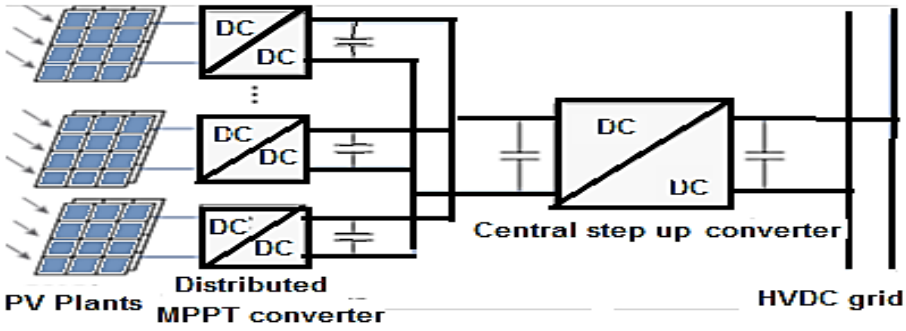

Fig. 10. System outline of the proposed HVDC grid-connectedPV system [7].

The the hereinafter researches are depends on the MPPT technique are subjected to the following classification which can be applied on the large and small capacities and even to hybrid units. Figs (11- 14) show the different technieqs of MPPT systems. Figure (15) Shows the the different MPPT classification used.

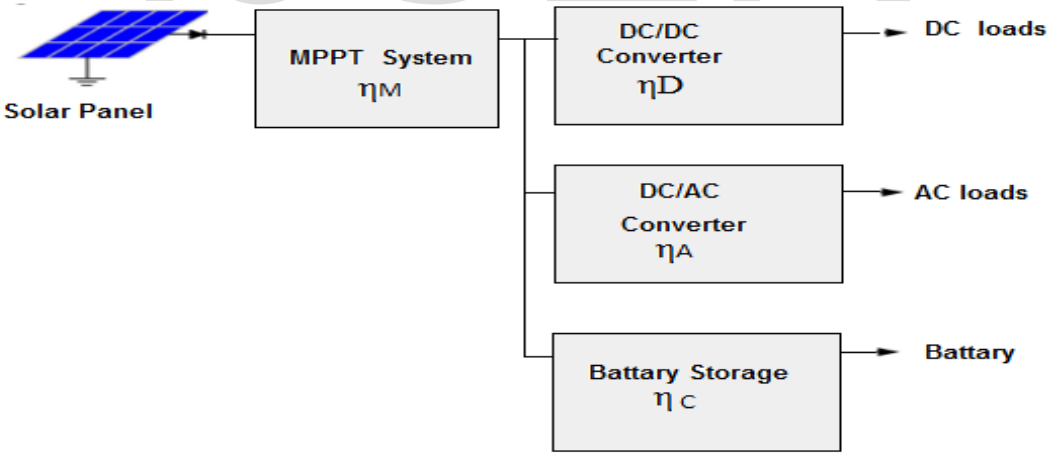

Fig. 11. Conventional photovoltaic power storage system [8].

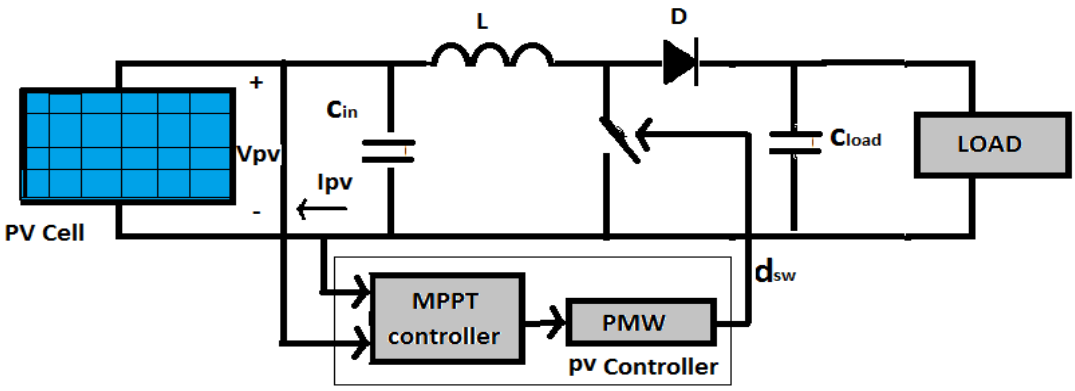

Fig. 12. Photovoltaic power system [9].

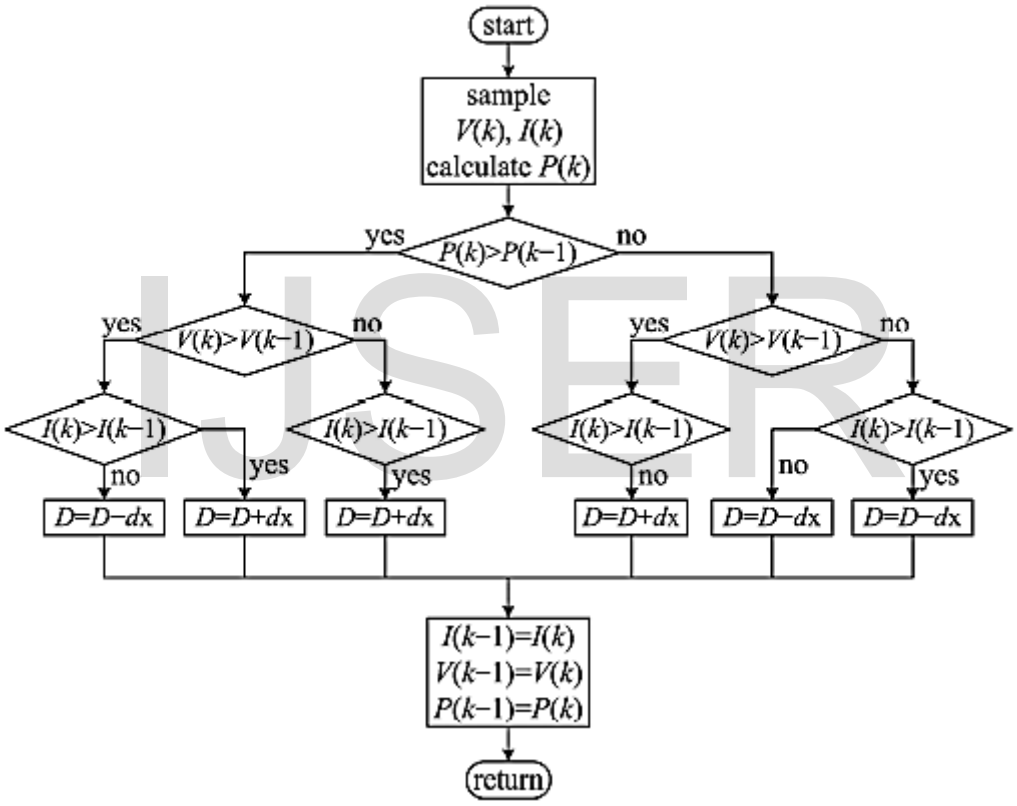

Fig.13. Flow chart of the proposed MPPT algorithm [9].

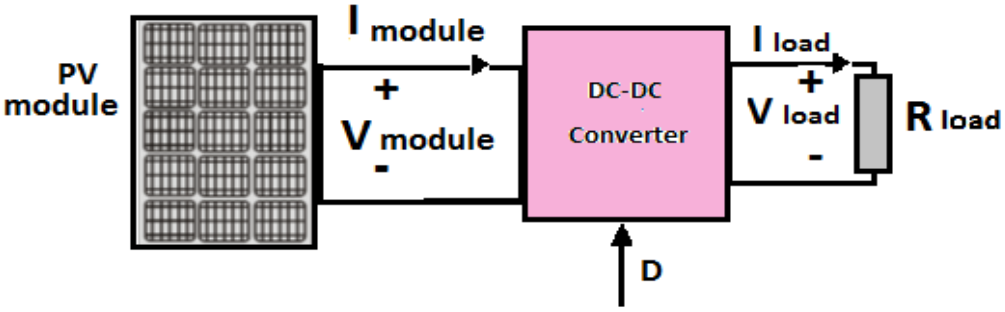

Fig.14. Photovoltaic module connected to a load through a DC-DC converter [10].

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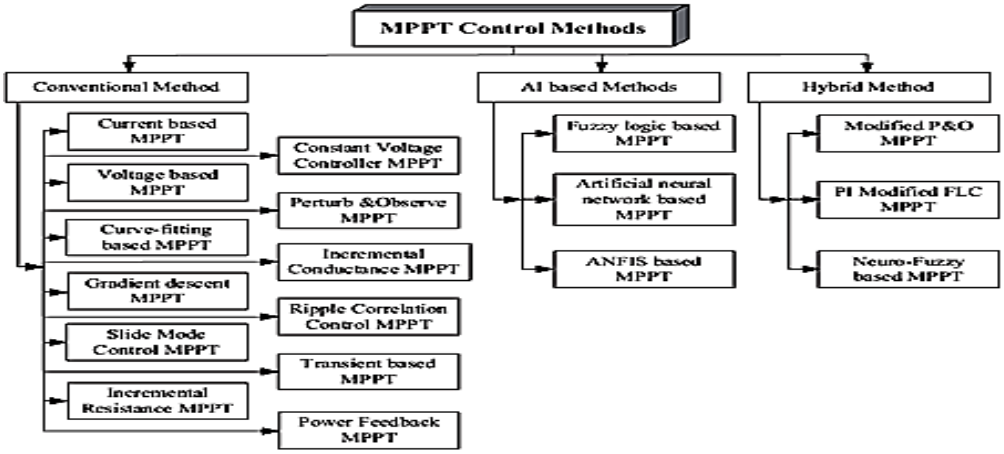


Fig. 15. Classification of MPPT control methods.

In [11], They inject a power of single stage photovoltaic grid to the public net through system designed in the laboratory Fig (12). They purposed system has high effectiveness by use a dSPACE DS1103 controller built in the laboratory. This system is able to get MPPT point through its unit which received the power from the photovoltaic plates.

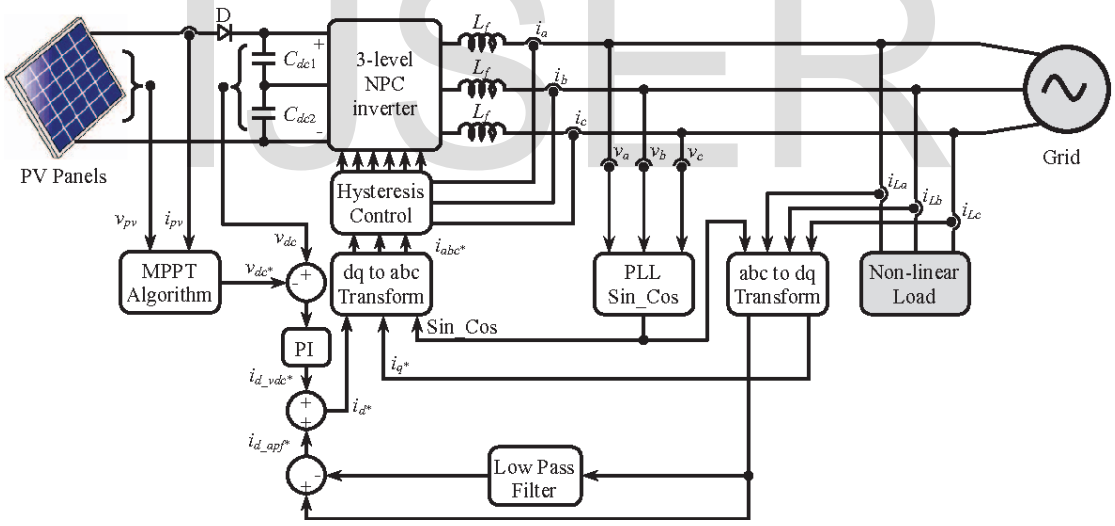


Fig. 16. The block diagram for controlling single-stage grid-connected PV system with APF function [11].

In [12], They presented an algorithm based on the Global Maximum Power Point Tracking (GMPPT) method which is operating for photovoltaic systems under partial shading conditions. This algorithm can be better applied to the GMPPT problems and examined under several cases of partial shading.

In [13], They developed the main construction arrangement for several groups of the photovoltaic system. This architecture was having high efficiency of MPPT based on the multi-sting configuration which is the most promising compromise between efficiency and the total cost.

In [14], In their work they studied the BOOST type converter to get the MPPT point related to the maximum power and simulated the results to prove the system effectiveness and stability of power.

B- nonlinear load power generation units.

some reaserchs were introducd in the literature . In a large number of times load is applied to the generating station and it occurs that there is a change in load is instantaneously changing and this is normal for the nature of the provision of electrical services. As the photovoltaic units have the same function as the other electrical power stations. Therefore, there is a group of researches based on the assistance in the application of electrical systems working to maintain the components of the unit of equipment and controls and auxiliary tools to ensure the unit's validity to work at all times, to kept the unit continuously under operation these tens to maintenance cost. These groups are:-

In [15] They decided that the quality of the energy would be important in the PV systems if in case of the non linear systms. These non-linear loads were increased in electrical distribution systems. The distributed nature of harmonic charges can be considered important and essential for the loads stability. The quality of distributed energy (PQI) is unavoidable.

In [16] Their design has been shown to be capable of detecting faults at the panel level while minimizing the wiring for the purposes of communication shown in Fig. (17) .Their system was consists of a composed of two modules are combine and display / alarm. The combination module will have voltage sensors, a current sensor, and a microcontroller for controting the unit

The FSK has been connected to control the sensors using the microcontroller. To prevent power and protect the modem using high voltage and DC coupling capacitor, which will install the high-frequency AC (AC) signal on the DC power provided by the PV panels. The display / alarm module will be mounted near the inverter and to be used to demodulate of the FSK signal and display the current, these is a control loop to kept the equipment under safe operation continuously.

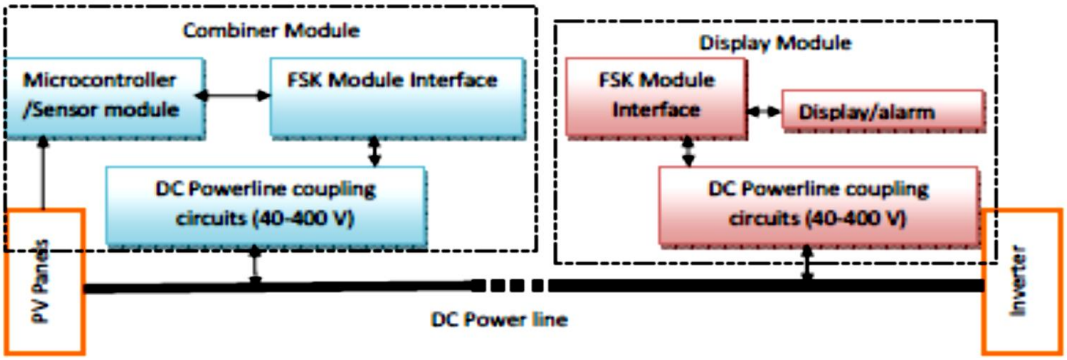


Fig. 17. Smart combiner keeping the equipment [16].

In [17], They have developed electronic energy technology by combining nonlinear loads into energy systems. They have studied the characteristics of electric spring operation with linear loads. It was ascertained that the electric spring achieves voltage regulation, harmonic compensation, and correction of the cadre factor at one time. So they reached the correct analysis and control strategy Electric spring (ES) is a complete control device to develop the power received by the all renewable energy units. Dynamic Voltage Restorer (DVR) is a power electronic-based device that protects critical loads from voltage unbalances. It is connected in series with the sensitive load and can absorb power fluctuation of the grid. It needs an energy storage source that can be a battery, capacitor, ultra-capacitor and superconductive energy storage (SMES) [18]. Nowadays in many applications play the role of storage sources, in this case not only it can improve the power rating but also it will decrease the storage source cost. It is worth noting that there is a slight difference between these devices and the multi-functional DGs that can do both of the roles of the power delivery source. An isolated transformer is inevitable in the unit structure to isolate the DC and AC sides and to protect the device over the fault conditions of the grid [19].

C. Generating units are working under Neural Network to obtain the maximum power generation.

In [20], They have developed a real algorithm that helps to offset the errors associated with the near-future prediction of photovoltaic generation of photovoltaic cells that can predict the photovoltaic potential to meet their challenges. This system can predict for three days to come. This is done using the solar radiation software engineering technology and the Elman Neural Network (ENN) technology using photovoltaic power relationships with solar radiation, temperature, humidity and wind speed data. ENN has also been applied to have a significant impact on the random time series of PV power. Figs (18) and (19) are explain the theoretical neural network and real net.

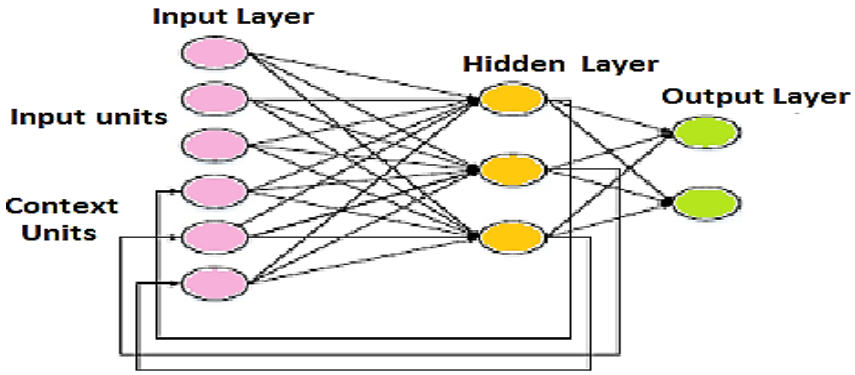


Fig. 18. Structure of Elman Neural Network [20].

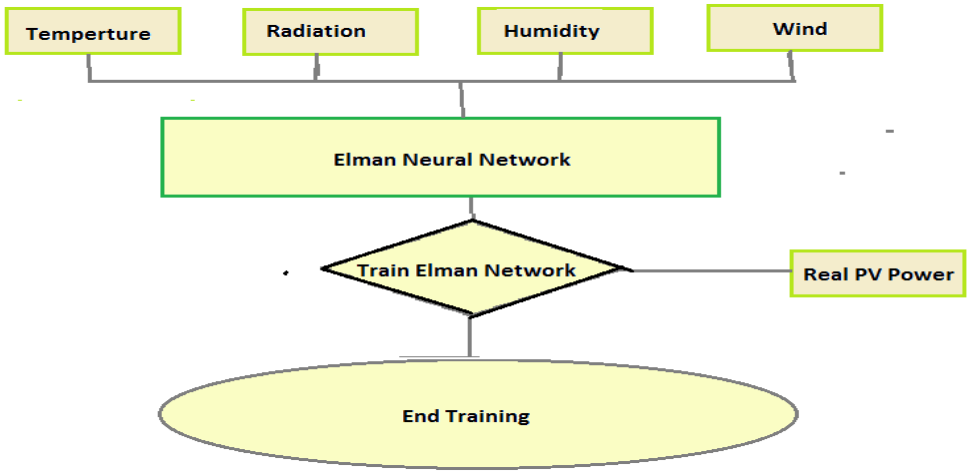


Fig. 19. Elman neural network algorithm [20].

Their numerical results showed that their suggested method attains better prediction accuracy. In this way, the numerical method described above will be able to obtain accurate results and will be a reference basis for future energy generation plans

D. Units working with the use of devices to stabilize the amount of energy generated

Improving energy , ifficiency and performance in photovoltaic generation units is a fertile field for researchers working in this field to improve them. By using, developing, and inventing equipment, can be connected to inverter, converter and electric springs, connected with some electronic circuits that work to get the highest possible power from the unit while improving its effenicieny and performance.

Below review some of the research published in this field:-

In [21], They have designed a highly efficient electric circuit after studying special gradationally controled voltage inverter GCVI techniques which is a highly efficient reflector. The GCVI consists of several transformers working with different voltage in a series and produces an effort through the shape of a sine wave by combining these outputs. The main advantages of GCVI features are a low power loss, low electromagnetic noise, small output filters, and higher AC voltage generation than the DC voltage input in the GCVI and also helps the DC / DC adapter to operate efficiently... The GCVI, PV-PN40G, high power efficiency, 97.5% at the maximum power point, has a closed, quiet structure at 30 dB.

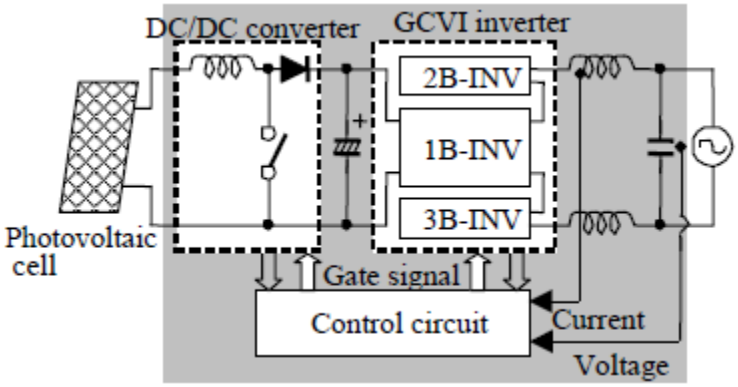


Fig. 20. A GCVI type power conditioner [21].

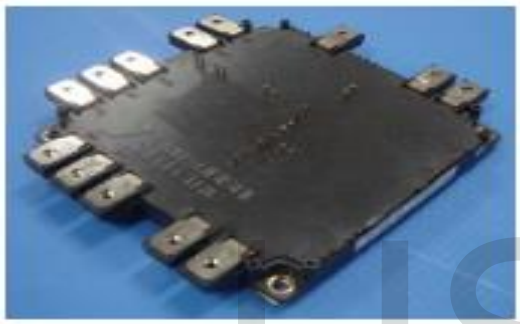


Fig. 21. The power semiconductor module developed for exclusive use [21].

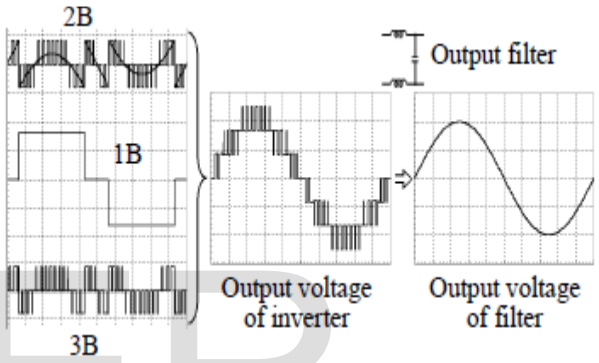


Fig. 22. GCVI Voltage waveforms of each inverter for three inverters and forms a stepped sine voltage wave [21].

Some researchers approach [21] in improving energy, performance and quality. Some of these are the addition of electronic control circuits , additive devices, the search for digital programs in the field of research, some using platforms and control panels. The following are some of the papers that are shared with [21] in this goal [22] and [23].

In [24], Distribution networks suffer from overvoltage when exceeding the capacity of PV panels. One solution to overcome voltage is to control the power factor of those systems. A simulation was performed using the DIGSILENT program. A graphical analysis of the voltage profile across the feeder was performed with three different conditions in three different cases. It has become necessary to install power factor identification units and reduce plant load, which ensures the carrier to load the station to equal the applied load. The results of these studies conclude that the control of the power factor of the solar PV reflector improves the voltage profile, thus alleviating the problem of overvoltage.

In [25], A new concept for the use of a solar power station to connect the photovoltaic PV system between transmission lines (possibly more) and through the reconfiguration of existing photovoltaic solar transformers enables this newly

developed system to act as a FACTS device that can flexibly control both active and interacting forces on multiple lines at the same time. The PV system can be implemented during the night hours when the photovoltaic solar power plant does not produce any energy. The configuration process can be realized during daylight hours as well. The interline PV system can be used to regulate the transmission / distribution line voltages, inductive support to load VAR requirements, to improve system performance during dynamic disturbances, and to manage real power flow between two or more interconnected lines. A MATLAB / SIMULINK simulation was performed to demonstrate the concept of control of the internal PV system.

In [26], It is evidence that the battery's energy life is dependent on their operation mode. Buffer mode, characterized by supporting batteries in a charged state, is more preferable.

In cyclic mode resource performance of batteries determined is an allowable depth of discharge, which is not recommended to increase by more than 30%. Consequently, the daily electricity volume of the battery.

charge-discharge in the autonomous photovoltaic power should not exceed 30% of its total energy. It will lead to the necessity of choosing 100% energy battery capacity, exceeding more than3times of energy charge-discharge value. Energy volume's decline, transmitted via battery storage, significantly decreased its overall capacity. It leads to a magnificent cost economy of energy storage and improves PV power supply system's economic characteristics.

Some studies provide good ideas about ways to ensure the stability of work in solar photovoltaic plants under the stability of applied loads when changing the solar load. With the multiplicity of these methods and with the different methods of control is working to identify those methods and to stand on the diversity of control methods with changing capacities [27-37].

E. Power quality improvement with Electrical Spring (ES)

In a solar power station, a set of electrical components consisting of the spring is designed and connected to the panels that are generating the electric current. To regulate this electric load it is required a control circuit to regulate the electrical load by a DC spring that is connected to the electric current (DC / AC) Inverter). This output is connected to the public network.

Abundant researches that offer modules working with springs. It is clear from these researches that the springs do a very important job in organizing the work of units that work with photovoltaic, wind-powered and some other types of renewable energies. Working with springs the unit helps to produce a constant source of electricity despite the change in the source load resulting from the act of nature.

The review of these researches as following:-

In [38] a new control scheme for the implementation of the electric spring was presented in this paper. The search provides a system of non-critical load control and Vader provides the system's energy factor correction, voltage support, and a current balance of critical loads, such as the building's security system, as well as the current electrical properties of zinc and voltage stability. Therefore, the prospective control system opens up new ways to use the electric spring to a large extent by providing voltage and energy stability and enhancing the quality of energy in small, renewable energy networks. Fig (23) shows the circuit componenets of an electric spring.

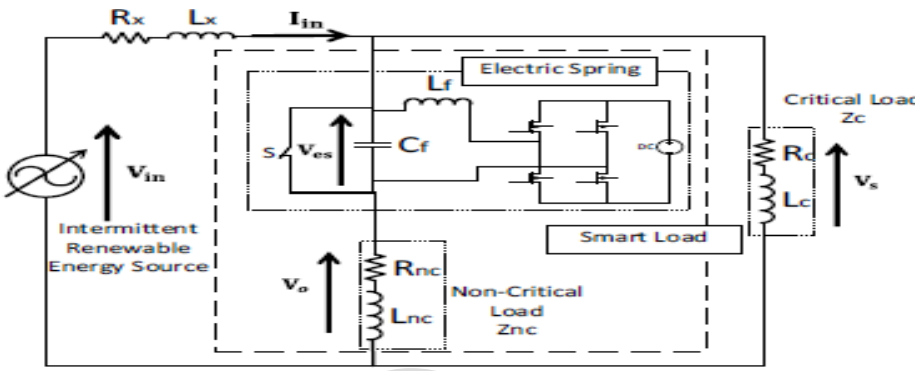


Fig. 23. Electric spring – circuit representation [38].

Also, ES properties can be used to form the line current, Iin, to correspond in phase with the VS line voltage. Phasor schemas in Fig. 24 which shows how the V es voltage compensator can help improve the power factor in a distribution system that provides dynamic power and voltage support in a load resistor system, meaning that it has a fully backward energy factor. [38]

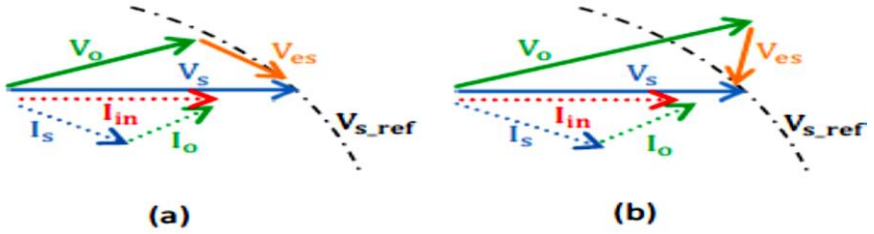


Fig. 24. Phasor diagrams of Voltage and Current for PFC and Voltage Support in (a) Under-voltage conditions (b) Over-voltage conditions. Vs, Vo, and Ves are voltages across the critical load, non-critical load, and electric spring, respectively and Are Io, and I in are currents through the critical load, non-critical load, and line current, respectively [38].

In [39], the authors have conducted studies to determine the effect of load variation on electric springs. A simulation program has been built for two different circuits. The two phones have been equipped with a variable energy resistor with electric spring. The experiment was repeated with multiple springs. The load voltage is

adjusted regardless of the variation in the source voltage. They also conducted a brief comparative study between the simulation results obtained from both circuits to observe the effect of the additional electric spring. Their study tests the efficiency of electric springs in a circuit designed to be more realistic, ie, when loads are not running all the time and multiple electrical springs are distributed throughout the grid. .Figures (25 and 26) show the electrical circuit of their spring test unit.

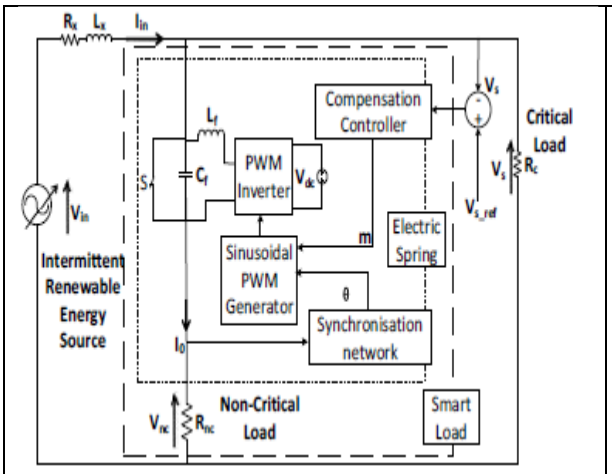


Fig. 25. Schematic of Electric Spring (ES) Coupled with Intermittent Renewable Energy Source.

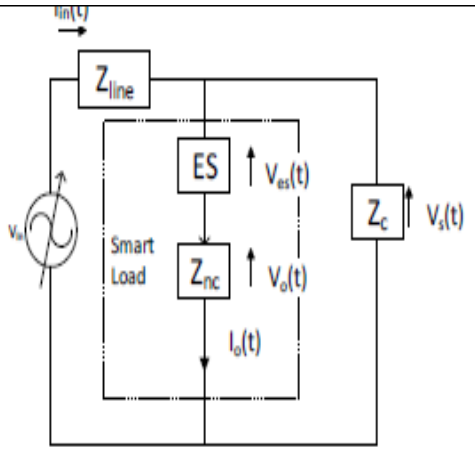


Fig. 26. Smart Load Controlled with Electric Spring.

In [40], A new system has been proposed to control the problems of DC networks using the AC-type electric spring, which works on the ease and dynamism of DC transmission as shown in Fig (27). The work of the electric spring was analyzed by connecting with the NC load to work with other loads and indicating their operating conditions. The electrical springs are designed to improve the operating limits.

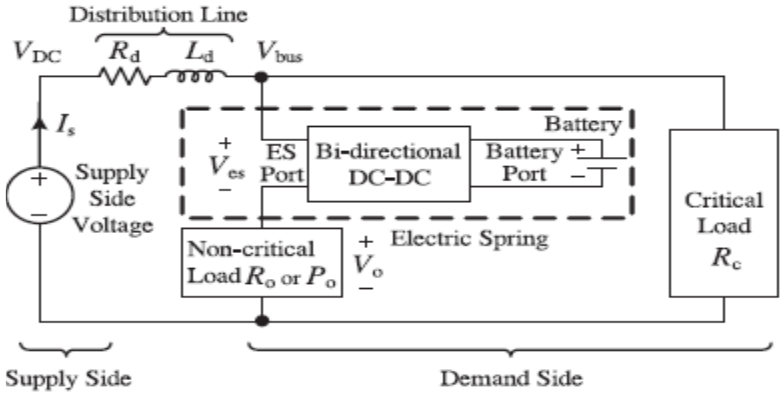


Fig. 27. Basic configuration of DC-ES [40].

In [41], They introduced an experimental study for adjusting the source energy fluctuation with electrical spring. The electrical spring maintains a constant voltage to the critical loads and passes the fluctuation to the non-critical louds electrical springs were realized using voltage source inverter .the electrical spring in their paper is realized using current source inverter and using in new control called direct current control which is reducing THD values across critical load this control enable to get a clean sin wave across the critical load and although achieved using high stress current control. For this purpose they built a control circuit contains inverter and electrical switch currunt source inverter (CSI) and its equivalent circuit explained in Fig 23.

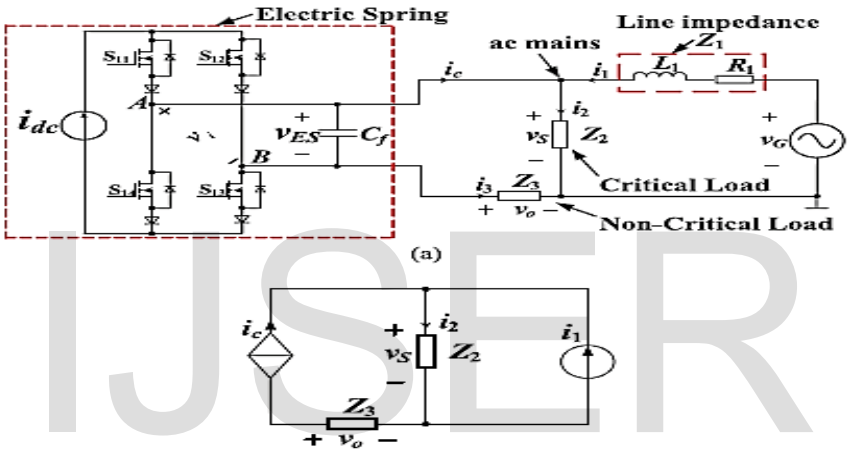
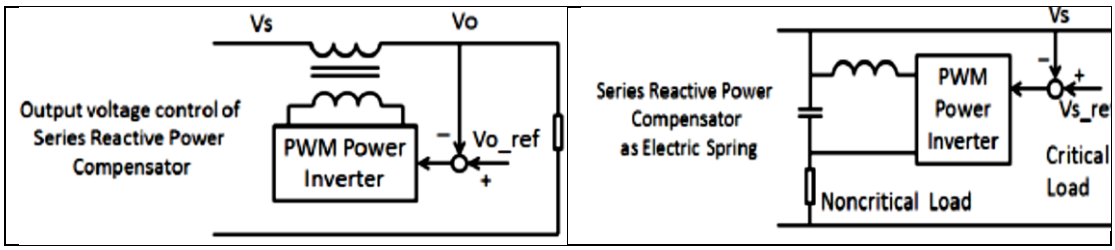


Fig. 27. Electrical spring with CSI and its equivalent circuit [41].

In [42], Y Shuo et al carefully studied the principle of electric spring operation (ES) as an interactive power compensator and as a correct energy factor. The theoretical review of voltage-related capacitor-related voltage springs to provide a general and clear understanding of the behavior of ES The focus of further discussion and a good understanding of the work of electric springs with interconnecting networks was verified to verify their ability to correct the power factor. A low-voltage single-phase power system with different load types is designed to verify the feasibility of the proposed ES theory with batteries. Their experimental results show that ES is capable of performing the eight operating modes when changing the energy consumption of the non-critical load and that with the current input control, ES can achieve the power factor correction for both RL and RC. In Fig (28) a and b shows: (a) the simplified control diagram of the series RPC and (b) a simplified diagram of ES



(a)	(b)

Fig. 28. (a) The simplified control diagram of the series RPC, (b)Simplified diagram of ES

Electric springs are mainly designed to accomodate the power generated from renewable energy sources and maintain stability of islanded microgrids. Due to the variety of stations and the variety of energies generated in these energies of the stations, the need to use electric springs became are necessary. The following researches clearly emphasize the need to apply the electrical spring systems on renewable energy plants, especially in the field of solar photovoltaic. The following papers are concerned with the electric springs in the literature of [43-49].

III. Conclusion

As the era of fossil energy has started the decay towards the end, the need to have a feasible alternative renewable energy resources has become crucial for the global stakeholders of energy-sectors. This paper explores the recently presented and published articles in the international publishing houses on renewable energy. To avoid distraction and confusion, the paper here considers only the solutions and strategies that are related to solar PV energy. The published research found that it contains the following classification:-

1- Nonlinear load and PV generation units.
2- Neural network algorithms to obtain the maximum power generation.
3- Units working with the use of devices to stabilize the amount of energy generated.
4- Power quality improvement with Electric Spring (ES).

Electric springs were found very promising as they can provide the key features to standalone PV microgrids:

1-Maintaining and storing generation capacity,
2-Improve system reliability, and
3- improve voltage stability despite of source and load changes

It is worth to mention that there are several conditions for electric springs. The most known circumstances of ES include:

• Connect with non-critical normal load with the interactive power component and a storage system is required.

• The spring is connected to a series of normal load while providing a storage system.
• Connect the spring in parallel with a small network without the need for a storage system.

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