# Design of Photovolatic Based Dvr For Power Quality Improvement Using IOT

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***Abstract***- *Voltage sags result in unwanted operation stops and large economic losses in industrial applications. A dynamic voltage restorer (DVR) is a power-electronics-based device conceived to protect high-power installations against these events. However, the design of a DVR control system is not straightforward and it has some peculiarities. First of all, a DVR includes a resonant (LC) connection filter with a lightly damped resonance. Secondly, the control system of a DVR should work properly regardless of the type of load, which can be linear or non-linear, to be protected. In order to improve the utilization rate and power quality of distributed new energy power generation technology and, to solve the voltage fluctuation problem in the operation of the distributed photovoltaic storage and grid-connected system. This project proposes a control strategy based on DVR (dynamic voltage restorer) for operation of distributed photovoltaic storage and grid-connected. The remaining photovoltaic output energy is stored in energy storage via active bridge to reduce the waste of photovoltaic power.*

*To compensate the output voltage fluctuation of photovoltaic grid-connected inverter, the DVR was connected to the energy storage. And PI controller parameters of the DVR are optimized by ANFIS algorithm, realize the recovery of output voltage fluctuation of the photovoltaic grid-connected inverter. The advantages of the proposed control strategy are demonstrated using simulations, and the results show that the proposed strategy can ensure the quality of PV output voltage in the photovoltaic storage and grid connected. PV based DVR system is comprised of PV System with low and high-power DC-DC boost converter, PWM voltage source inverter, series injection transformer and semiconductor switches. Simulation results proved the capability of the proposed DVR in mitigating the voltage sag, swell and outage in a low voltage distribution system.*

***Keywords***- C PIC16F676, ESP8266, Photovoltaic cell, PWM Drive.

## I. INTRODUCTION

Most downtimes in industry are due to voltage sags. Unfortunately, it is difficult to immunize equipment against these voltage events and, if the sag lasts for a long time, equipment shutdown is inevitable. Uninterruptible power supplies (UPSs) are often used for protecting sensitive loads against voltage sags. UPSs are widely applied to protect low-power loads such as computers or small electronic loads. They replace the grid when a voltage sag takes place and, when the voltage level recovers, loads are gently reconnected to the grid. However, a UPS has to deliver all the power consumed by the protected loads during a sag. This means that a UPS requires large batteries to protect loads against long-duration voltage sags and, consequently, its application is greatly restricted by the size and cost of batteries. A dynamic voltage restorer (DVR) is conceived to protect sensitive loads. against voltage sags and swells.

This device is connected in series with an electrical distribution line and, typically, it consists of a voltage source converter (VSC), a DC capacitor, a coupling transformer, batteries, and an AC filter. When voltage sag takes place, a DVR injects the required voltage in series with the feeding line and the load voltage remains unchanged. The main advantage of DVRs is that only a portion of the power consumed by the load is supplied from the batteries. This means that batteries can be made much smaller than in a typical UPS and cost can be reduced. These reductions in battery size and cost make DVRs very attractive for high-power applications where a UPS may be infeasible. A series-connected power-electronics device that was able to restore the voltage of a load under distorted grid conditions. AC–DC converter was used to maintain the DC voltage constant so that no additional energy storage elements were required. The main task of a DVR is to control the load voltage. Therefore, a control scheme is commonly adopted. DVRs are sometimes controlled by using open-loop techniques. Stability is guaranteed with this control technique if the plant is stable (always the case for a DVR).

## II. RELATED WORKS

[1]PV-BASED DYNAMIC VOLTAGE RESTORER FOR POWER QUALITY ENHANCEMENT IN DISTRIBUTION SYSTEMS AUTHOR: ZEINAB ELKADY AHMED MANSOUR NASER ABDEL-RAHIM-PV-based dynamic voltage restorer (DVR) is considered one of the most effective solutions for enhancing the functionality of the PV grid system by adding ancillary functions to the grid side inverter. DVR protects against voltage sag and swell based on pulse width-modulated (PWM) voltage source inverters. This paper investigates the performance and analysis of three phase DVR based on synchronous reference frame (SRF) theory. The control algorithm has been developed for the generation of compensating reference voltage vector to inject or absorb active and reactive power in series between the point of common coupling and critical load. The results presented in the paper show that the proposed control algorithm has excellent performance in both steady–state and dynamic phases.[2]VOLTAGE PROFILE AND POWER QUALITY IMPROVEMENT IN PHOTOVOLTAIC FARMS INTEGRATED MEDIUM VOLTAGE GRID USING DYNAMIC VOLTAGE RESTORER AUTHOR: ABDELKRIM BENALI, MOUNIR KHIAT, MOULOUD DENAI-In this paper, we have presented a simulation study to analyse the power quality of three phases medium voltage grid connected with distribution generation (DG) such as photovoltaic (PV) farms and its control schemes. The system uses two-stage energy conversion topology composed of a DC to DC boost converter for the extraction of maximum power available from the solar PV system based on incremental inductance technique and a three-level voltage source inverter (VSI) to connect PV farm to the power grid. To maintain the grid voltage and frequency within tolerance following disturbances such as voltage swells and sags, a fuzzy logic-based Dynamic Voltage Restorer is proposed. The role of the DVR is to protect critical loads from disturbances coming from the network. Different fault conditions scenarios are tested and the results such as voltage stability, real and reactive powers, current and power factor at the point of common coupling (PCC) are compared with and without the DVR system. [3]DYNAMIC VOLTAGE RESTORER (DVR) BASED ON ARTIFICIAL NEURAL NETWORK (ANN) AND PHOTOVOLTAIC DESIGN FOR POWER QUALITY IMPROVEMENT AUTHOR: M.DIVYA BHARATHI, G.PARANJOTHI-In the present electric power grids, power quality issues are recognized as a crucial concerns and a frequently occurring problem possessing significant costly consequence such as sensitive load tripping and production loss. Consequently, demand for high power quality and voltage stability becomes a pressing issue. Dynamic voltage restorer (DVR) is one of the most effective solutions for “restoring” a custom power device, the quality of voltage at its load-side terminals its source-side terminals is disturbed when the quality of voltage and new DVR topology based medium voltage application has been proposed on double flying capacitor multi-cell (DFCM) converter. The advantage of the proposed DVR is that it does not need any line frequency step-up isolation transformer, which is bulky and costly, to be connected to medium-voltage power grid. The proposed DVR topology obtains the required active power from the energy storage feeding the dc link of the DFCM converter. The pre-sagcompensation method, which is explained in detail, is used to restore amplitude and angle of the sensitive load voltage. Moreover, an approach based on d-q synchronous reference frame to determine DVR reference voltages is utilized. The proposed DVR topology is simulated and results to illustrate its performance under various conditions of voltage sag compensation are provided. [4]COMPREHENSIVE DESIGN AND ANALYSIS OF A STATE-FEEDBACK CONTROLLER FOR A DYNAMIC VOLTAGE RESTORER AUTHOR: JAVIER ROLDÁN-PÉREZ, AURELIO GARCÍA-CERRADA, ALBERTO RODRÍGUEZ-CABERO AND JUAN LUIS ZAMORA-MACHO Voltage sags result in unwanted operation stops and large economic losses in industrial Applications. A dynamic voltage restorer (DVR) is a power-electronics-based device conceived to protect high-power installations against these events. However, the design of a DVR control system is not straightforward and it has some peculiarities. First of all, a DVR includes a resonant (LC) connection filter with a lightly damped resonance. Secondly, the control system of a DVR should work properly regardless of the type of load, which can be linear or non-linear, to be protected. In this paper, a digital state-feedback (SF) controller for a DVR is proposed to address these issues. The design and features of the SF controller are studied in detail. Two pole-placement alternatives are discussed and the system robustness is tested under variations in the system parameters. Furthermore, implementation aspects such as discretization not commonly addressed in the literature are described. The controller is implemented in its incremental form. A decoupling system for the dq-axis dynamics that takes into account system delays and the load current is proposed and analytically studied. The proposed controller is compared with two other alternatives found in the literature: a Proportional-Integral-Differential (PID) controller and a cascade controller. The effect of the load connected downstream a DVR is also studied, revealing the potential of the SF controller to damp the resonance under light load conditions. All control system developments were tested in a 5 kVA prototype of a DVR connected to a configurable grid.[5]DESIGNING OF A SOLAR ENERGY BASED SINGLE PHASE DYNAMIC VOLTAGE RESTORER USING FUZZY LOGIC CONTROLLED NOVEL BOOST

INVERTER.AUTHOR: MOHIT BAJAJ, AMIT KUMAR SINGH In this work, an energy-efficient and reliable model of photovoltaic based single phase Dynamic Voltage Restorer (DVR) is proposed in order to mitigate severe voltage sags, swells, and interruptions affecting the sensitive equipment connected in low voltage distribution side. In case of short or long duration interruption, it can fulfil the load power requirement acting as a UPS. Fuzzy logic controlled novel boost inverter improves overall efficiency and dynamic performance of the DVR system. Further, it is also designed to solve the voltage quality problem of distribution system with the minimum usage of energy from the utility grid and in the most efficient way by making optimal usage of solar energy. The proposed DVR system model involves two PV systems with low power DC to DC converter, chargeable batteries, switches, fuzzy logic controlled SPWM based boost inverter implemented by two DC to DC boost converters and one injection transformer for each phase under sag/swell. The results obtained after simulation verifies the effectiveness of the proposed model of DVR in recovering the voltage sag/swell and interruption on the low voltage side of the distribution. The DVR model proposed is found capable of recovering voltage sag up to 0.1 p.u. and swell up to 1.9 p.u. of pre-sag voltage.

## II. SYSTEM DESIGN

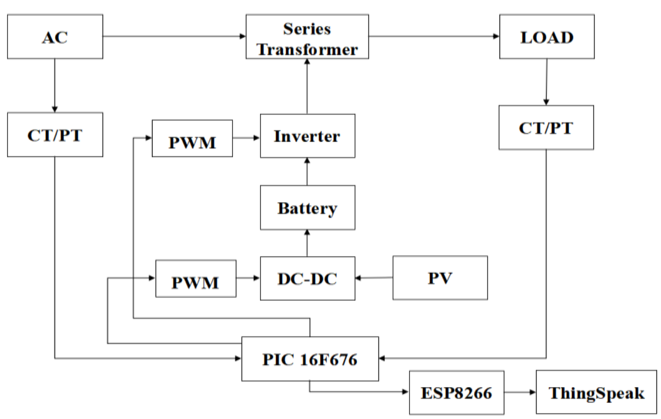


**Figure.1 Block Diagram**

Dynamic Voltage Restorer (DVR) is one of the best methods to address voltage sag problems. DVR is a solid state device which consists of energy storage device and injection transformer that injects the voltage into the system in order to regulate the load side voltage . DVR is connected in the distribution system between the supply and load. the DVR During the normal operation as there is no sag, DVR will not supply any voltage to the load. When there is a voltage sag in distribution side, DVR will generate a required controlled voltage of high magnitude and desired phase angle which ensures that load voltage is uninterrupted and is maintained.. The difference between the pre sag voltage and the sag voltage is injected by the DVR by supplying the real power from the energy storage element together with the reactive power.

### 1. CT/PT:

#### a) Current Transformer:

A **current transformer** (**CT**) is a typeof transformer that is used to reduce or multiply an alternating current (AC). It produces a current in its secondary which is proportional to the current in its primary. Current transformers, along with voltage or potential transformers, are instrument transformers. Instrument transformers scale the large values of voltage or current to small, standardized values that are easy to handle for measuring instruments and protective relays. The instrument transformers isolate measurement or protection circuits from the high voltage of the primary system. A current transformer provides a secondary current that is accurately proportional to the current flowing in its primary. The current transformer presents a negligible load to the primary circuit. Current transformers are the current-sensing units of the power system and are used at generating stations, electrical substations, and in industrial and commercial electric power distribution.

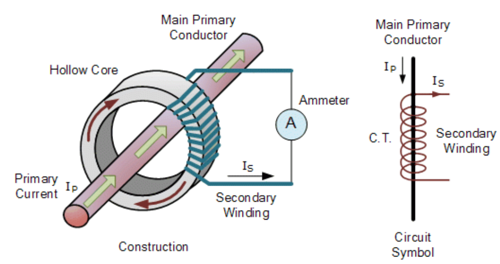


**Figure.2 Current Transformer**

#### b) Potential Transformer:

**Voltage transformers (VT)**, also called **potential transformers (PT)**, are a parallel-connected type of instrument transformer. They are designed to present a negligible load to the supply being measured and have an accurate voltage ratio and phase relationship to enable accurate secondary connected metering.

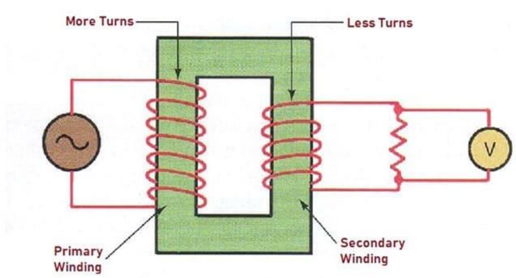


**Figure.3 Potential Transformer**

## 2. PHOTOVOLTAIC CELL:

Conversion of light energy in electrical energy is based on a phenomenon called photovoltaic effect. When semiconductor materials are exposed to light, the some of the photons of light ray are absorbed by the semiconductor crystal which causes a significant number of free electrons in the crystal. This is the basic reason for producing electricity due to photovoltaic effect. **Photovoltaic cell** is the basic unit of the system where the photovoltaic effect is utilised to produce electricity from light energy. Silicon is the most widely used semiconductor material for constructing the photovoltaic cell. The silicon atom has four valence electrons. In a solid crystal, each silicon atom shares each of its four valence electrons with another nearest silicon atom hence creating covalent bonds between them. In this way, silicon crystal gets a tetrahedral lattice structure. While light ray strikes on any materials some portion of the light is reflected, some portion is transmitted through the materials and rest is absorbed by the materials.

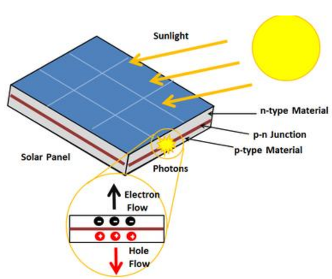


**Figure.4 Photovoltaic cell**

The same thing happens when light falls on a silicon crystal. If the intensity of incident light is high enough, sufficient numbers of photons are absorbed by the crystal and these photons, in turn, excite some of the electrons of covalent bonds. These excited electrons then get sufficient energy to migrate from valence band to conduction band. As the energy level of these electrons is in the conduction band, they leave from the covalent bond leaving a hole in the bond behind each removed electron. These are called free electrons move randomly inside the crystal structure of the silicon. These free electrons and holes have a vital role in creating electricity in **photovoltaic cell**. These electrons and holes are hence called **light-generated electrons and holes** respectively. These light generated electrons and holes cannot produce electricity in the silicon crystal alone.

## 3. BATTERY:

A lead-acid storage battery is an electrochemical device that produces voltage and delivers electrical current. The battery is the primary "source" of electrical energy used in vehicles today. It's important to remember that a battery does not store electricity, but rather it stores a series of chemicals, and through a chemical process electricity is produced. Basically, two different types of lead in an acid mixture react to produce an electrical pressure called voltage. This electrochemical reaction changes chemical energy to electrical energy and is the basis for all automotive batteries.

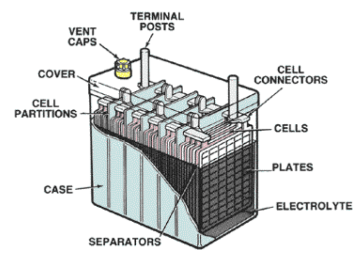


**Figure.5 Battery**

1. **BATTERIES - Primary or Secondary**
   Batteries can either be a primary cell, such as a flashlight battery once used, throw it away, or a secondary cell, such as a car battery (when the charge is gone, it can be recharged).

2. **PRIMARY CELL:**
   Because the chemical reaction totally destroys one of the metals after a period of time, primary cells cannot be recharged. Small batteries such as flashlight and radio batteries are primary cells.

3. **SECONDARY CELL:**
   The metal plates and acid mixture change as the battery supplies voltage. As the battery drains the metal plates become similar and the acid strength weakens. This process is called discharging. By applying current to the battery in the reverse direction, the battery materials can be restored, thus recharging the battery.

## 4. INVERTERS:

An inverter is a motor control that adjusts the speed of an AC induction motor. It does this by varying the frequency of the AC power to the motor. An inverter also adjusts the voltage to the motor. This process takes place by using some intricate electronic circuitry that controls six separate power devices. They switch on and off to produce a simulated three phase AC voltage. This switching process is also called inverting DC bus voltage and current into the AC waveforms that are applied to the motor. This led to the name “inverter”. For the rest of this discussion, the term **“inverter”** will be used in place of **adjustable speed drive**.

**Figure.6 Inverter**

**5. PWM DRIVE:**

**Pulse-width modulation** (**PWM**), or **pulse-duration modulation** (**PDM**), is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. Along with maximum power point tracking (MPPT), it is one of the primary methods of reducing the output of solar panels to that which can be utilized by a battery. PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching, because their inertia causes them to react slowly. The PWM switching frequency has to be high enough not to affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible.


**Figure.7 PWM Drive**

**6. PIC 16F676:**

**PIC16F676** is a small-sized **pic microcontroller**, which is one of the best options for embedded applications. Most of the industrial and home appliances required a small number of pins and small memory space, which can be fulfilled by PIC16F676. It is reliable for student projects due to its high performance which is enhanced due to flash-based technology. PIC16F676 may be smaller in size but it has internal 10Bit Analog to Digital converter within a 14-pin package. The PIC Microcontroller also comes in multiple packages and every package consist of 14 pins. The **internal flash memory** of the microcontroller is 2kb which is excellent for small projects and especially for developing a small program.

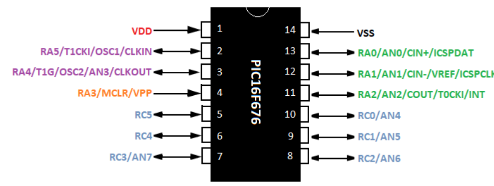


**Figure.8 Pic16f676**

**7. ESP8266:**

The **ESP8266** is a low-cost Wi-Fi microchip, with built-in TCP/IP networking software, and microcontroller capability. The chip first came to the attention of Western makers in August 2014 with the **ESP-01** module, made by a third-party manufacturer Ai-Thinker. This small module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style commands. However, at first, there was almost no English-language documentation on the chip and the commands it accepted. The very low price and the fact that there were very few external components on the module, which suggested that it could eventually be very inexpensive in volume, attracted many hackers to explore the module, the chip, and the software on it, as well as to translate the Chinese documentation.

**Figure.9 ESP8266**

**8. THINGSPEAK:**

In this report we describe the use of Thingspeak, an “Application Programming Interface” (API) and web service for the “Internet of Things” (IoT). While the interpretation as to what should be understood under the term is changing over time, here we refer to enabling objects or simple devices to be identified and communicated with via the Internet. The Thingspeak API is an open-source interface which listens to incoming data, timestamps it, and outputs it for both human users (through visual graphs) and machines (through easily parse-able code). We look into practical examples using the Arduino micro-controller as well as communication with graphical interface operating systems through a Python script. Our report concludes that Thingspeak is especially useful for smaller hardware projects where connectivity over the Internet is required but in which the maintenance of a dedicated communication server is not practical. Alternative IOT services exist but tend to require payment for some of their functionality and are consequently not open source.

## IV. RESULT

The performance of the proposed PV-TEG integrated DVR system was examined for voltage disturbance compensation as well as grid energy conservation. An AC source with a 50 Hz frequency with a line-to-line voltage of 240 V was used. Initially, the power output by the hybrid PV-TEG energy module was examined to confirm its suitability for the DVR operation. The power output of the hybrid energy module for an irradiation of 1000 W/m2 with a standard temperature of 300 K and a temperature difference of 30 K between the cold and hot sides of the TEG. It was confirmed that the hybrid energy source can provide the stable and necessary power for DVR operation.

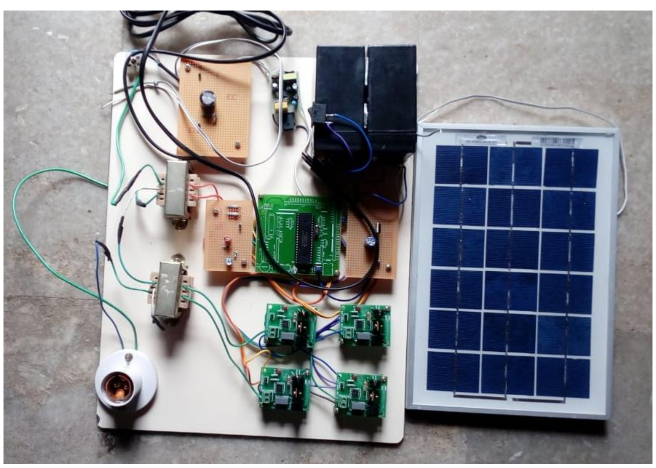

**Figure.11 Kit Snapshot**

The power output of the PV-TEG hybrid source was also compared with the standalone PV array output power. Evidently proved that the power output of the hybrid energy module was greater with the inclusion of TEG. Hence, the TEG produced a reasonable amount of power from the waste heat energy developed because of the solar irradiation on the PV panel. Similarly, the efficiency of the standalone PV and the PV-TEG hybrid module are compared. It was observed that the efficiency of the PV combined TEG energy module showed efficiency 2.5% higher than the standalone PV module. Therefore it was confirmed that the PV-TEG hybrid energy module can supply enough power to the DVR for power quality compensation. The performance of the proposed DVR system is demonstrated with the following five different case studies.

## V. CONCLUSION AND FUTURE SCOPE

This project has presented the power quality problems such as voltage dips, swells, distortions and harmonics. Compensation techniques of custom power electronic devices DVR was presented. The design and applications of DVR for voltage sags and comprehensive results were presented. A PWM-based control scheme was implemented. As opposed to fundamental frequency switching schemes already available in the MATLAB/ SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications. Design and implementation of solar energy-based three phase DVR, using fuzzy logic controlled novel boost inverter, for mitigation of deep voltage sags, swells and an interruption affecting the sensitive equipment connected on low voltage distribution side, has been proposed. The proposed model of DVR has been simulated in MATLAB/Simulink. The proposed DVR system model utilizes solar energy stored in the battery for mitigation of voltage sags, swells and interruptions hence result in huge cost saving for consumer side and reduces the payback period of the DVR system. It stores the solar energy in separate back up for night time utilization purpose rather than drawing energy from the grid which minimizes the usage of grid energy and increases the reliability of DVR for the consumer. Further fuzzy logic controlled novel boost inverter improves overall efficiency and dynamic performance of the DVR system.

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