International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 14 Issue 1 –APRIL 2015.

FLEXIBLE AC DISTRIBUTED SYSTEM USING VOLTAGE SOURCE INVERTER FOR A MICROGRID

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***Abstract*-The micro grid has offered consumers with increased reliability and reduction in total energy losses, and has become a promising alternative for traditional power distribution system. The connection of a micro grid to the distribution grid is the impact of power quality (PQ) problems on the overall power system performance. These PQ problems include voltage and frequency deviations in the grid voltage and harmonics in the grid voltage and load currents. To overcome the aforementioned PQ problems, several power-conditioning equipment such as active filters uninterruptible power supplies dynamic voltage restorers and unified PQ conditioners are usually employed by consumers to protect their loads and systems against PQ disturbances in the distribution network. However, these devices are usually installed at the consumer sides and the PQ problems that they are capable to handle are usually limited. This work proposes a flexible ac distribution system device for the micro grid that is realized using a combination of series and shunt voltage source inverters (VSIs). The proposed device is installed at the point of common coupling (PCC) of the distribution grid that the micro grid and other electrical loads. Hence by this device the power quality and the reliability of the system can be improved. The Extended Kalman filters are employed to extract the harmonic spectra of the grid voltage and the load currents in the micro grid. All the details of the work and Simulation results using MATLAB are presented.**

***Index terms*–Extended Kalman filter; Microgrid; Model predictive control; power quality; Voltage source inverter.**

I. Introduction

A nonlinear load has caused many power quality problems like high current harmonics, low power factor, voltage and frequency deviations. Nonlinear loads appear to be current sources injecting harmonic currents into the supply network through the utility's Point of Common Coupling (PCC). This results in distorted voltage drop across the source impedance, which causes voltage distortion at the PCC. Other customers at the same PCC will receive distorted supply voltage, which may cause overheating of power factor correction capacitors, motors, transformers and cables, and mal-operation of some protection devices. Flexible AC distribution system device has been proposed to reduce power quality (PQ) problems and installed at the consumer side. The device used a combination of series and shunt voltage source inverters (VSIs).voltage source inverter consists of five levels. The device is installed at the PCC of the distribution grid and based on Multi-Input–Multi-Output (MIMO) state-space model. A Micro grid and electrical loads are connected to the PCC. Flexible AC distribution system device consists of the photovoltaic array (PV) and a battery to store the excess energy generated by the PV array and to provide power during sunless hours .The device can provide real and reactive power to the micro grid during islanded operation. The device is equipped with the capability to improve the PQ and reliability of the micro grid. The Model predictive controller (MPC) have been proposed to track periodic reference signals for fast sampling linear time invariant (LTI) systems that are subject to input constraints. The controller based on the MPC algorithm. The MPC controls the input signals of the VSIs and decomposes the control problem into steady-state and transient sub problems are optimized separately. Using MPC, computational times can be greatly reduced. Extended Kalman filters are used for frequency tracking and to extract the harmonic spectra of the grid voltage and the load currents in the micro grid. Voltage source inverters (VSIs) is proposed in this project which provided significant advantages over the three level inverter(existing method) are low harmonic, low voltage distortion, high efficiency and also power quality problems are less. The control strategies for a three phase five level VSI integrating Micro grid and distribution grid. The PV array and battery are connected to the VSI through a boost converter and a buck–boost converter. To facilitates charging and discharging

operations for the battery and to regulate the DC-link voltage at the desired level. In power distribution system is suffering from severe power quality problems. These power quality problems include sag, swell and harmonic in the grid voltage and load currents etc. The flexible AC distribution system device aims to improve the power quality and reliability of the overall power distribution system. The device compensate the harmonic in grid voltage and load currents, power factor correction at the grid side, real and reactive power control. Voltage and frequency variations in the grid voltage are reduced. The device delivers the real and reactive power to the micro grid in islanded mode operation.

II. Proposed Voltage Source Inverter

Voltage source inverter converts the electric power from DC type energy sources to AC type load. Voltage source inverter connected between the grid and micro grid network. Increase the level of VSI from three levels to five levels. To increase the level of voltage source inverter for decreasing the harmonics and reduces the power quality problems DC side is constant voltage, low impedance and AC side voltage is square wave or quasi square wave.AC side current is determined by the Load. The Anti parallel diodes are necessary to provide energy feedback path. Low voltage switches can be used in five-level inverters. These are faster, smaller and cheaper than high voltage switches used in three-level inverters. When switches are in series, they withstand higher voltages. Five level inverters offer better magnitude of output square Wave voltage and effective value of output voltage. This causes the THD to be lower. To compensate harmonic are very quickly. Switching losses are reduced because switching frequency can be lower than in three level inverter and also the switching speed is faster with low voltage switches than with high voltage switches that are usually needed in three level inverters.

Circuit Diagram

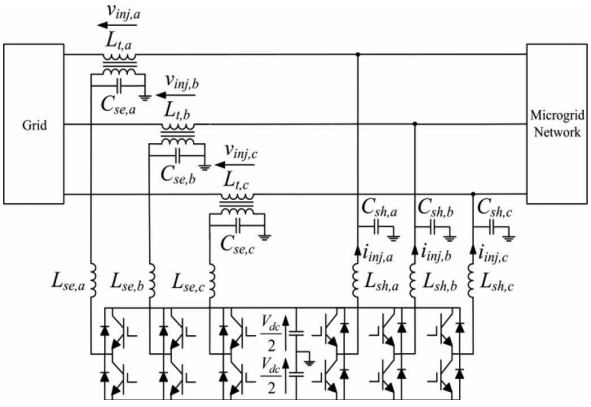

Figure 1Circuit Diagram of Proposed System

Circuit Operation

The micro grid can operate in two modes. During grid-connected operation, the micro grid is connected to the distribution grid at the PCC. In this mode, the two DG units are controlled to provide local power and voltage support for loads 1 to 3.To reduce the burden of generation and delivery of power directly from the utility grid. Nonlinear loads are connected at the PCC, to present harmonic in grid voltage and load currents for a micro grid. The device operated in two modes. First one is power quality compensation mode, the Energizing of large loads and rapid changes in the load demand may result in voltage and frequency variations in the grid voltage, when the generation capacity of the micro generators is unable to meet the total load demand, the device transits to operate in the emergency mode. A flexible AC distribution system device compensate harmonic and also capability to handle the voltage and frequency variations the grid voltage. When a fault occurs on the upstream network of the grid, the circuit breakers (CB) operate to disconnect the micro grid from the grid. The DG units are sole the power sources left to regulate the loads. In the case when the generation capacity of the micro generators is unable to meet the total load demand, the flexible ac distribution system device transits to operate in the emergency mode and functions to momentarily provide for the shortage in real and reactive power.

III. System Design

PV Array

A PV system is an interconnection of modules which in turn is made up of many PV cells in series or parallel. The power produced by single module is not enough to meet the requirements of commercial applications, so modules are connected to form array to supply the load. In an array the connection of the modules is same as that of cells in a module. A photovoltaic system is an arrangement of components designed to supply usable electric power for a variety of purpose, using the Sun as the power source. The modules in a PV array are usually first connected in series to obtain the desired voltages; the individual modules are then connected in parallel to allow the system to produce more current. In urban uses, generally the arrays are mounted on a rooftop. PV array output can directly feed to a DC motor in agricultural applications.

Buck Boost Converter

The buck–boost converter is a type of DC-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. Both of them produce a range of output voltages, from an output voltage much larger

(in absolute magnitude) than the input voltage, lowered to almost zero.

A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is the class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, capacitor, inductor, or the two in combination.

Model predictive control

Model predictive control is a control method based on MPC algorithm. This specifically designed for fast-sampling systems like the flexible AC distribution system device to track periodic signals. This algorithm decomposes the MPC optimization into two sub problems: a steady-state sub problem and a transient sub problem, which are solved in parallel in different time scales, thus reducing the computational burdens. To apply the MPC algorithm, the state-space model and are discredited with a sampling interval of T_s = 0.2 ms, which is considered pretty fast in conventional MPC applications but necessary in our problem for the high order of harmonics being tackled.

A more conventional approach of MPC that employs a finite horizon with a terminal cost is adopted. The information required by the MPC includes us and x_s, which will be provided by the solution of the steady-state sub problem, and the plant state x, which can be estimated using a plant Kalman filter. The centre of area method is used in this MPC controller. The use of three levels VSI instead of five level VSI the transient response of the AC distribution system device is very fast.

Block diagram

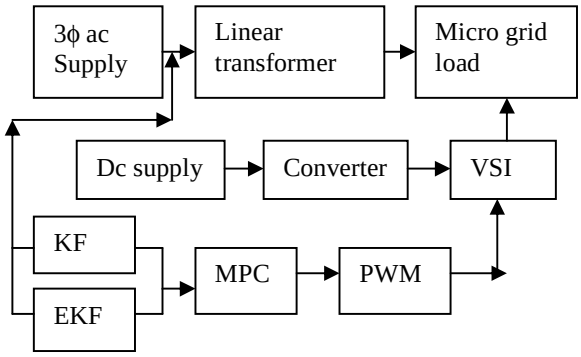

Figure 2 Block Diagram of Proposed System

Grid

Grid computing is the collection of computer resources from multiple locations to reach a common goal. The grid can be thought of as a distributed system with non-interactive workloads that involve a large number of files. What distinguishes grid computing from conventional high performance computing systems such as cluster computing is that grids tend to be more loosely coupled, heterogeneous, and geographically dispersed. Although a single grid can be dedicated to a particular application, commonly a grid is used for a variety of purposes. Grids are often constructed with general-purpose grid middleware software libraries.

Kalman filter

Kalman filtering, also known as linear quadratic estimation (LQE), is an algorithm that uses a series of measurements observed over time, containing noise (random variations) and other inaccuracies, and produces estimates of unknown variables that tend to be more precise than those based on a single measurement alone. More formally, the Kalman filter operates recursively on streams of noisy input data to produce a statistically optimal estimate of the underlying system state.

The algorithm works in a two-step process. In the prediction step, the Kalman filter produces estimates of the current state variables, along with their uncertainties. Once the outcome of the next measurement (necessarily corrupted with some amount of error, including random noise) is observed, these estimates are updated using a weighted average, with more weight being given to estimates with higher certainty. Because of the algorithm's recursive nature, it can run in real time using only the present input measurements and the previously calculated state and its uncertainty matrix; no additional past information is required. It is a common misconception that the Kalman filter assumes that all error terms and measurements are Gaussian distributed. Kalman's original paper derived the filter using orthogonal projection theory to show that the covariance is minimized, and this result does not require any assumption, that the errors are Gaussian. He then showed that the filter yields the exact conditional probability estimate in the special case that all errors are Gaussian-distributed.

Extensions and generalizations to the method have also been developed, such as the extended Kalman filter and the unscented Kalman filter which work on nonlinear systems. The underlying model is a Bayesian model similar to a hidden Markov model but where the state space of the latent variables is continuous and where all latent and observed variables have Gaussian distributions.

IV. Simulation and Experimental Results

Swell Voltage Waveform

In distribution grid systems, harmonics occur when the normal electric current waveform is distorted by non-linear loads. When a three phase distribution grid system is connected with highly non-linear loads, it will affect the total system parameters and sag, swell voltages are presented. Swell voltage means source voltage suddenly increases because of lighting, mode of switching operations, and connecting non linear loads. Figure 3 shows the swell voltage waveform..

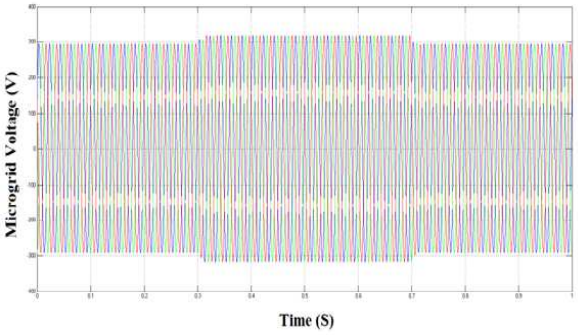

Figure 3 Swell Voltage Waveform

Sag voltage waveform

Figure 4 shows the sag voltage waveform.sag voltage means source voltage suddenly decreases because of connecting the non linear loads and using power electronic devices.

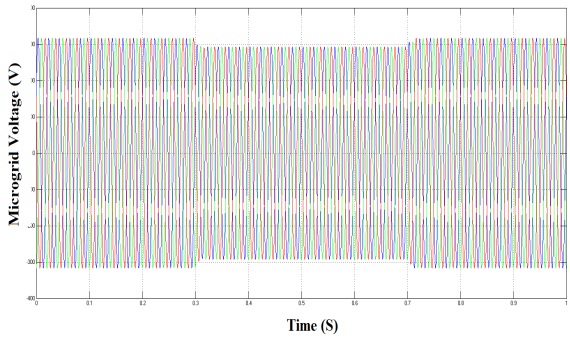

Figure 4 Sag Voltage Waveform

Real and reactive power waveform

When nonlinear load is connected, the power factor goes down .The power factor depends on the real and reactive power. Here the power factor goes to negative, because of more reactive power needed by the load side. The non-linear load is connected; the real and reactive power needed by this load will be very high. That is why the real and reactive power graph goes to the negative direction. But the source side cannot supply as much power needed by the load side. By this reason the source current waveform is highly distorted and unbalanced. Here the real and reactive power supplied by the source side is very small. That is why the power factor in the source side goes to very low value. Figure 5 shows the real and reactive power waveform.

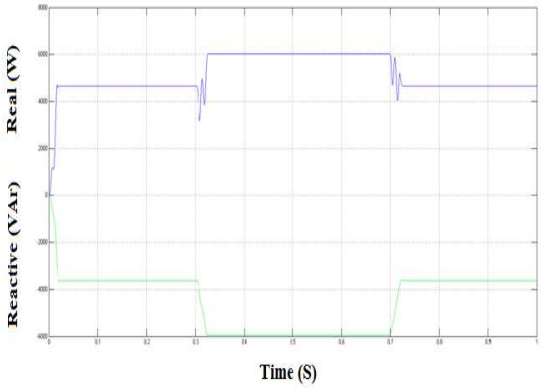

Figure 5 Real and Reactive Power Waveform

Five levels Waveform

Figure 6 shows the five levels waveform. The shunt converter injected current by the device. To achieve power factor correction at the grid side, the device is also controlled to provide the reactive component of the micro grid current. A Five level voltage source inverter injects in distribution line to compensate the sag and swell voltage.

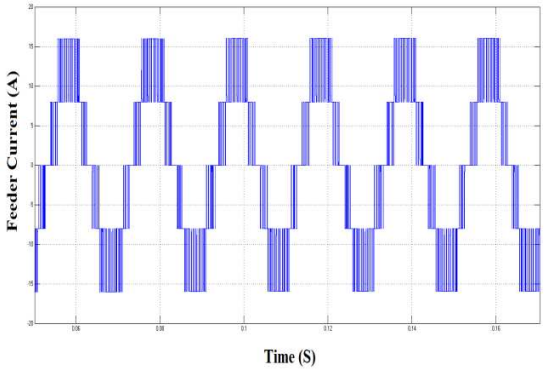

Figure 6 five levels Waveform

Output Voltage Waveforms

Figure 7 shows the output voltage waveform. Due to the power electronic load, the current and the voltage waveforms are unbalanced and distorted. The compensation is done using the AC Distribution System Device and it maintains the system voltage purely sinusoidal. The series injected voltage is represented by the figure 6. The series injected voltage is used to compensate the voltage related problems on the system**.** The device is also controlled to deliver real power to the micro grid during peak periods when the cost of generation from the grid is high. By doing so, the power required

from the grid is reduced and peak shaving is achieved.

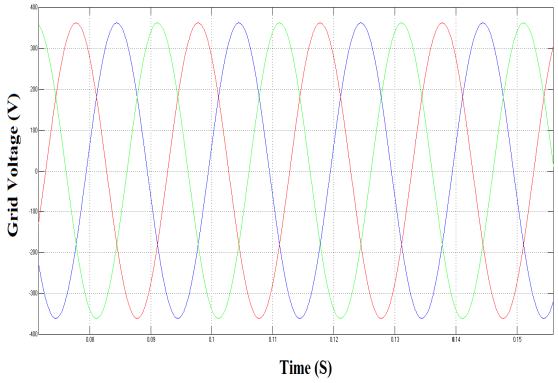

Figure 7 Output Phase Voltage Waveform

Output Real and Reactive Power Waveform

When reactive elements supply or absorb reactive power near the load, the apparent power is reduced. AC Distribution System Device is one of the effective custom power devices, which improves the power factor of the overall system. The device also delivers all the reactive power for required by the micro grid to achieve unity power factor at the grid side.

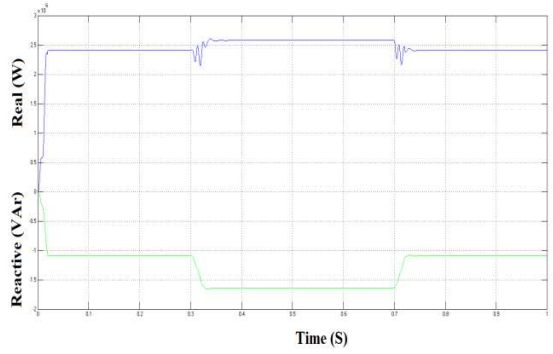

Figure 8 Real and Reactive Power Waveform

The three levels voltage source inverter has high amount of distortion in it and the Total Harmonic Distortion value is obtained.

Table 1 Comparison of the Proposed and Existing Method

Parameters	Proposed Method	Existing Method
Voltage(V)	Less power quality problems.	Sag, swell voltages are presented.

Table 1 gives a clear idea about the proposed five level voltage source inverters which can produce the output without too much harmonic, sag, swell and it is much more efficient than the three level voltage source inverters. Thus the analysis of both the inverters shows that the proposed five level voltage source inverters is more efficient and can be used in all fields.

V. Conclusion

The modeling of flexible ac distribution system device for power system configuration is done in MATLAB Simulink environment. The power quality problems in distribution systems are not new but customer awareness of these problems increased recently. It is very difficult to maintain electric power quality at acceptable limits. The present work mainly includes the grid supply power to the micro grid. The models are developed for five level voltage source to maintain source voltage under various loads and also controlled by model predictive control algorithm. In the existing method, harmonics, power quality issues such as sags, swells are the major problems. These problems are reduced by improve five level voltage source inverter.

MPC Algorithm is used to controls the input signal of the voltage source inverter and decomposes the steady-state and transient sub problem. The micro grid can provide an increased reliability and reduction total energy losses. Device compensates the harmonics in the grid voltage and load currents, real and reactive power control, power factor correction at the grid side.

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