Analysis of Distributed Flexible AC Transmission System Devices for Power System Control

M. Kaveri[1] | M. John Srinivasa Rao[2]

[1]PG Scholar, Department of EEE, Godavari Institute of Engineering and Technology, Rajahmundry, Andhra Pradesh, India.
[2]Assistant Professor, Department of EEE, Godavari Institute of Engineering and Technology, Rajahmundry, Andhra Pradesh, India.

ABSTRACT

This paper reviews the importance of a flexible ac distribution system device for microgrid applications. The device aims to improve the power quality and reliability of the overall power distribution system that the Microgrid is connected to. Extended Kalman filters are also studied for frequency tracking and to extract the harmonic spectra of the grid voltage and the load currents in the microgrid. Also this paper high lights on DG grouping in order to harmonize the investment of assets, the quality of power supply and the cooperation with the existing power grid.

KEYWORDS: *Extended Kalman filter, microgrid, Harmonized grouping, power quality, Security enhancement*

I. Introduction

For traditional power distribution system, the concept of microgrid has offered consumers a reliability and reduction in total energy losses and it has become a promising alternative.[1],[2] While connecting microgrid to the distribution grid, the impact of power quality (PQ) problem on the overall power system performance has to be considered. These PQ problem includes voltage and frequency deviation in the grid voltage and harmonics in the voltage and load currents. To mitigate these problem various equipments such as active filters[3],[4], uninterrupted power supplies[5],[6], dynamic voltage restorers,[7],[8] and UPQC [9] are usually installed by the consumers to protect their loads and system against PQ disturbances in distribution network. But these devices are installed at the consumer sides and the PQ problems that they are capable to handle are usually limited. In this paper a flexible ac distribution system devices are of series and shunt voltage source inverters (VSIs) for the microgrid. The device is installed at the point of common coupling (PCC) of the distribution grid that the microgrid and other electrical loads are connected to. Also, during islanded operation of the microgrid, the device can provide real and reactive power to the microgrid. The device will accomplish the following tasks simultaneously:

1. Compensating for harmonics in the grid voltage and load currents;
2. Real and reactive power control for load sharing during peak periods and power factor correction at the grid side;
3. Maintaining PQ despite slight voltage and frequency variations in the grid voltage; and
4. Momentarily dispatching real and reactive power to the microgrid when it becomes islanded.

II. System Architecture

The configuration of the microgrid considered in this paper for implementation of the flexible ac distribution system device is shown in Fig. 1. microgrid consists of three radial feeders (1, 2 and 3) where feeders 1 and 3 are each connected to a distributed generation (DG) unit consisting of a microgenerator, a three-phase VSI, and a three-phase LC filter. Feeder 2, however, is connected to an electrical load. The flexible ac distribution system device is operated in two modes: 1) PQ compensation and 2) emergency operation. During grid-connected operation, the microgrid 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 1–3 and hence reduce the burden of generation and delivery of power directly from the utility grid. The flexible ac distribution system device functions to compensate for any harmonics in the currents drawn by the nonlinear loads in the microgrid so that the harmonics will not propagate to the rest of the electrical loads that are connected to the PCC. The device also functions to compensate for harmonics in the grid voltage that are caused by other nonlinear loads that are connected at the PCC. The energization of large loads and rapid changes in the load demand may also result in voltage and frequency variations in the grid voltage. Therefore, the device is also equipped with the capability to handle such voltage and frequency variations.

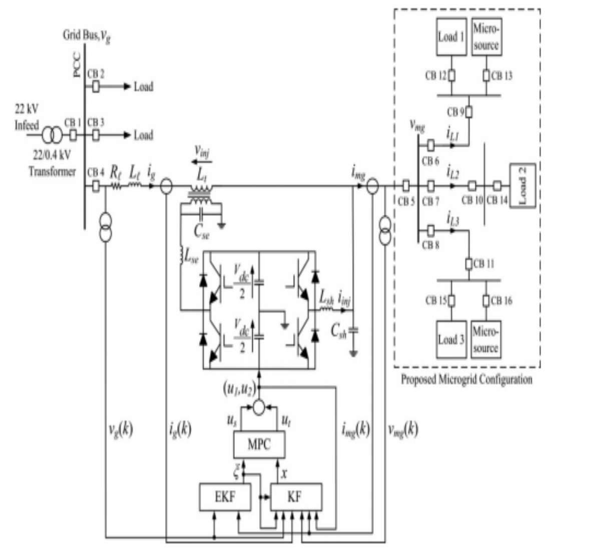


Fig. 1. Overall configuration of the proposed flexible ac distribution system device and the microgrid architecture with EKF denoting the extended Kalman filter and KF denoting t Kalman filter for the plant

When a fault occurs on the upstream network of the grid, the CBs operate to disconnect the microgrid from the rid. The DG units are now the sole 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. Flexiable AC Distribution System Device Model

The single-phase representation of the flexible ac distribution system device is shown in Fig. 3 [10]. The distribution grid voltage at the PCC and the total current drawn by the microgrid are modeled as vg and img, respectively. With the proliferation of power electronics equipment being connected to the distribution grid and the microgrid, both vg and img could be distorted due to the presence of harmonic components. Therefore, Vg is modelled as a source consisting of its fundamental Vf and harmonic Vh

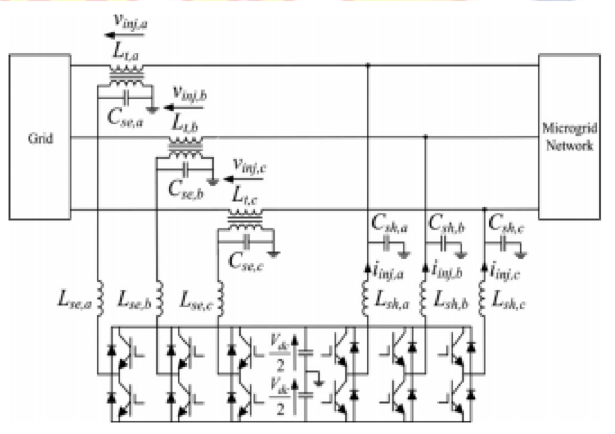


Fig. 2. Configuration of the three-phase flexible ac distribution system device.

In Fig. 2. the detailed configuration of the three phase flexible ac distribution system device is shown

that can be represented by

where vf is the fundamental component of Vg with its peak amplitude Vf and vh is a combination of the harmonic components of Vg with its peak amplitude Vh and phase angle θh . To compensate for the harmonics in Vg , the series VSI injects a voltage Vinj that is given by Vinj

Vinj = Vh − Vz – Vt (2)

Similarly, img is also modelled as two components consisting of fundamental if and harmonic ih with their peak amplitudes If and Ih, respectively and is represented by

where ϕf and ϕh are the respective phase angles of the fundamental and harmonic components of img, and if,p and if,q are the instantaneous fundamental phase and quadrature components of img. To achieve unity power factor at the grid side, compensate for the harmonics in the microgrid current and achieve load sharing concurrently, the shunt VSI injects a current iinj that is given by

iinj = (if,p − ig) + if,q + ih + iCsh

where ig is the grid current. The switched voltage across the series and shunt VSIs of the flexible ac distribution system device are represented by u1 (Vdc/2) and u2 (Vdc/2) , respectively. To eliminate the high switching frequency components generated by the series and shunt VSIs, two second-order low-pass interfacing filters which are represented by Lse, Cse, Lsh , and Csh are incorporated. The losses of the series and shunt VSIs are modeled as Rse and Rsh , respectively.

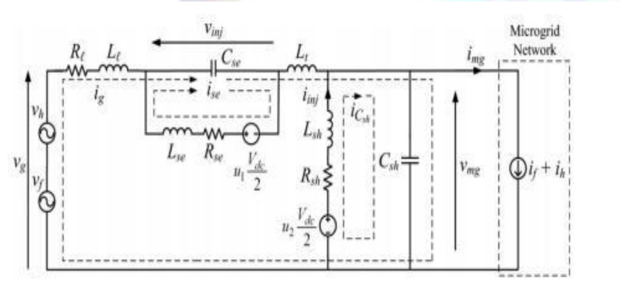


Fig. 3. Single-phase representation of the flexible ac distribution system device.

IV. PHOTOVOLTAIC ARRAY

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels comprising a number of cells containing a photovoltaic material. Materials presently used for photovoltaic include mono crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium serenade/sulfide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years

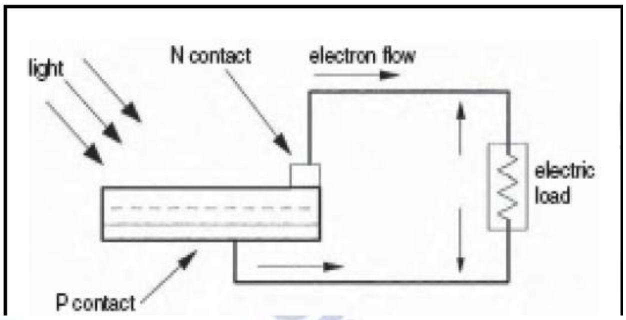
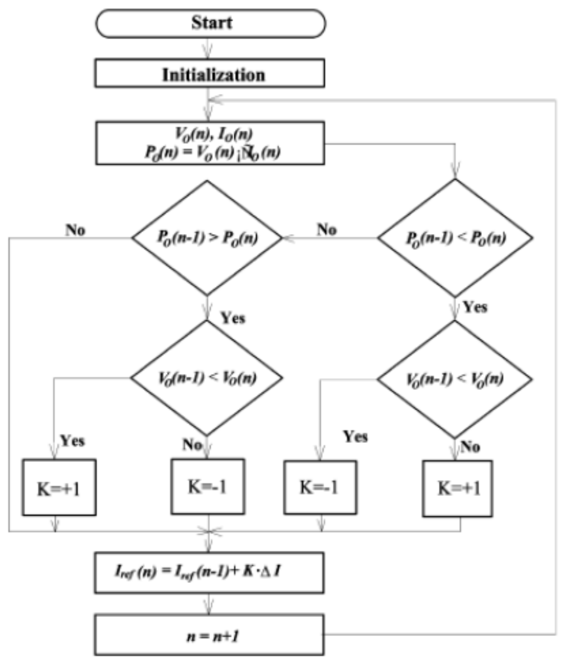


Fig.4 PV effect converts the photon energy into voltage across the pn junction

Fig 4:The photovoltaic effect is different in that the generated electrons are transferred between different bands (i.e. from the valence to conduction bands) within the material, resulting in the buildup of a voltage between two electrodes. In most photovoltaic applications the radiation is sunlight and for this reason the devices are known as solar cells. In the case of a p-n junction solar cell, illumination of the material results in the generation of an electric current as excited electrons and the remaining holes are swept in different directions by the built-in electric field of the depletion region.

V. MPPT CONTROLLER

Maximum power point tracker (or MPPT) is a high efficiency DC to DC converter that presents an optimal electrical load to a solar panel or array and produces a voltage suitable for the load. PV cells have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular load resistance, which is equal to V/I as specified by Ohm's Law. A PV cell has an exponential relationship between current and voltage, and the maximum power point (MPP) occurs at the knee of the curve, where the resistance is equal to the negative of the differential resistance (V/I = -dV/dI). Maximum power point trackers utilize some type of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell. Traditional solar inverters perform MPPT for an entire array as a whole. In such systems the same current, dictated by the inverter, flows though all panels in the string. But because different panels have different IV curves, i.e. different MPPs (due to manufacturing tolerance, partial shading, etc.) this architecture means some panels will be performing below their MPP, resulting in the loss of energy. Some companies (see power optimizer) are now placing peak power point converters into individual panels, allowing each to operate at peak efficiency despite uneven shading, soiling or electrical mismatch.



VI. Hybrid Source for DC Link Voltage

The proposed source for the dc-link voltage of the flexible ac distribution system device consists of a PV array and a battery as shown in Fig. 5. The PV array and the battery are connected to the VSI of the device through a boost converter and a buck–boost converter, respectively, to facilitate charging and discharging operations for the battery and to regulate the dc-link voltage at the desired level. To maintain the dc-link at the reference voltage V*dc/2, a dual loop control scheme in [14], which consists of an outer voltage loop and an inner current loop for the bidirectional converter, is implemented to compensate for the variation in the output voltage Vdc/2 of the dc/dc boost converter. In this section, the operation of the PV/battery system is briefly explained. When there is ample sunlight, the PV array is controlled by the dc/dc boost converter to operate in the MPPT mode to deliver its maximum dc power Ppv at Vdc/2, which induces a voltage error (V ∗dc/2 − Vdc/2) at the dc-link. The error is passed to a PI controller, which produces a reference battery current i∗ b for the inner current loop to operate the battery in either the charging mode for a positive error or discharging mode for a negative error. When the battery is in the charging mode, the bidirectional converter operates as a buck converter by turning switch Q3a OFF and applying the control signal from the controller to switch Q2a ON as shown in Fig. 6. Conversely, when the battery is in the discharging mode, the bidirectional converter operates as a boost converter by turning switch Q2a OFF and applying the control signal from the controller to switch Q3a ON as shown in Fig. 7. Figs. 6 and 7 illustrate the charging and discharging operations of Battery 1, so as to maintain the upper dc-link voltage at a desired value. The same charging and discharging operations are applied to Battery 2 such that the dc-link voltages for both the upper and lower dc-link capacitors are maintained at V ∗dc/2. When the PV array is subject to prolonged period of sunless hours and the state-of-charge of the battery falls below a preset limit, a selfcharging technique from the grid can be incorporated

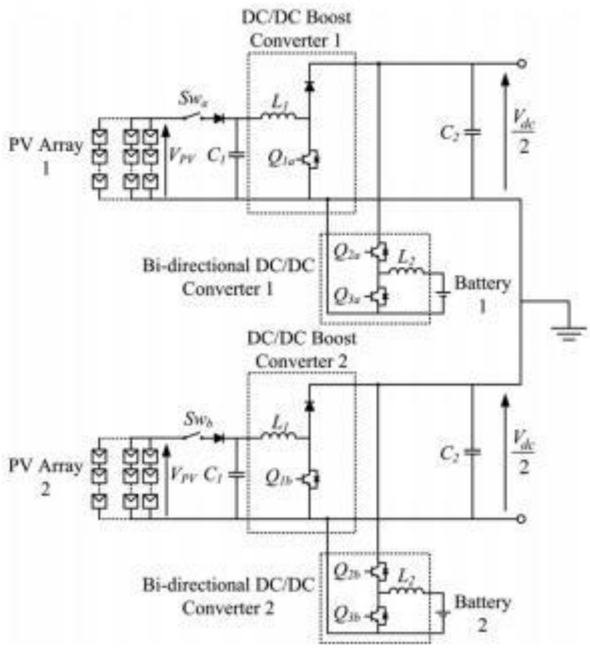


Fig.6:Proposed PV/battery system for the device.

VII. HARMONIZED GROUPING OF NATURAL RESOURCE DG AND SECURITY ENHANCEMENT

Output of the natural resource DG, such as the wind plant and the PV plant, is considerably fluctuated with the weather condition. The kW-balance of the total DG output and the demand has to be continuously maintained even in lots of uncertain factors. The battery can be used for absorbing the mismatch energy of the supply-demand balancing in the DG group. From the economical viewpoint, the harmonized grouping can be realized by minimizing the asset investment of the natural resource DG plants and the battery subject to the engineering constraints. The O&M cost, the quality of supply power, the environmental impact and other factors would be included for evaluating the performance of DG grouping. In the model analysis of the harmonized DG grouping, we assume that the kW-balance in the DG group is realized on the average value basis. Total kW-fluctuation of the natural resource plant has to be regulated by the adjustable power of the battery and the spinning reserve from the utility in order to maintain the specified quality of power supply.

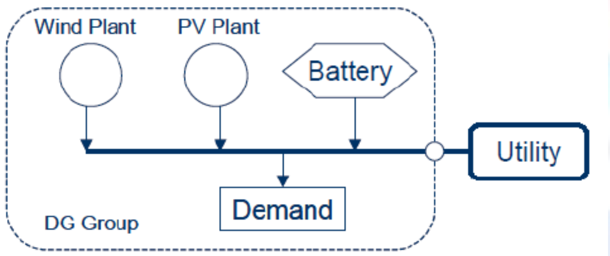


Fig 7 Typical Grouping of DG

VIII. SIMULATION RESULTS

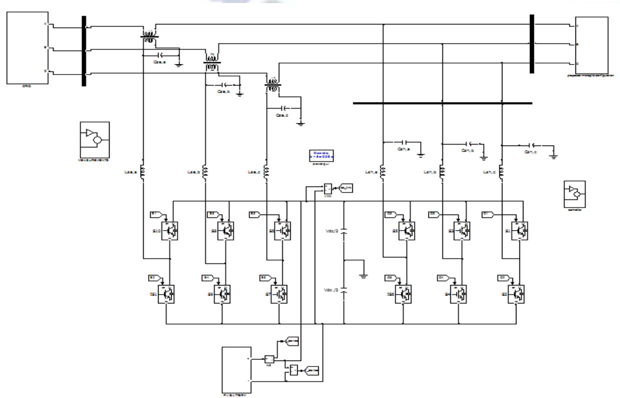


Fig8: Simulation implementation of Micro Grid

This simulation diagram for this system is shown in fig8: And results are verified under two cases.

Case 1: with PI Controller In this the conventional PI controller is used for series and shunt controllers. The obtained results are shown in below Figures

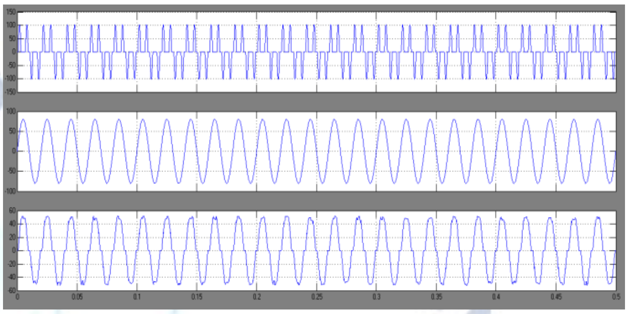


Fig8:Simulation result for Feeder currents 1, 2 and 3

Fig8:shows the simulation results for the system feeder currents under without and with compensation.

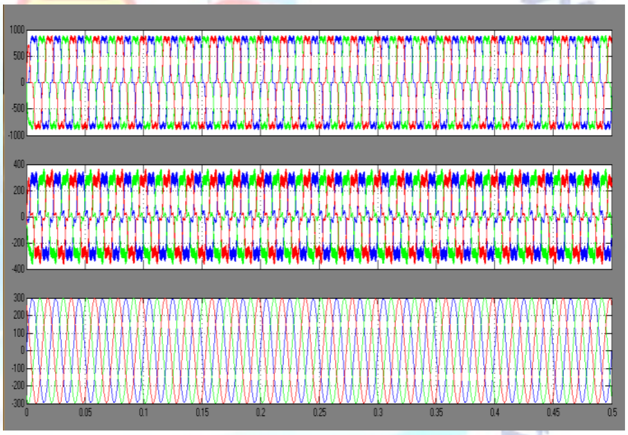


Fig9:Simulation result for Grid, Series Converter and Micro-Grid Voltage

Fig9: shows the simulation results for the system micro grid voltage under without and with compensation

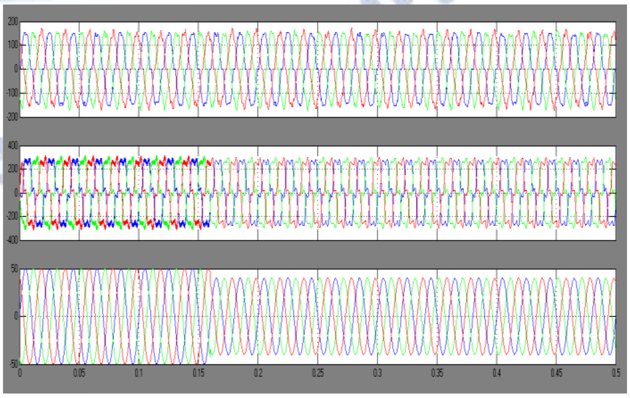


Figure 10:Simulation result for Grid, Series Converter and Micro-Grid Current

Figure 10:shows the simulation results for the system Micro-Grid Currents under without and with compensation

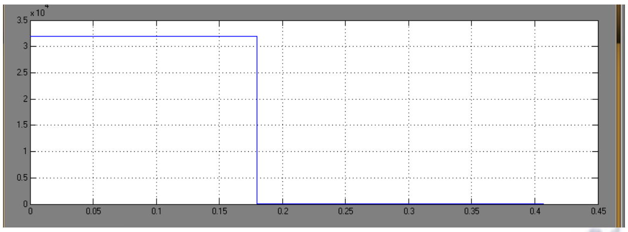


Fig 11: Simulation result for Active Power under Islanded condition

Fig11: shows the simulation result for the active and reactive powers under Islanded condition. In this case we consider the islanded condition at time t=0.17sec and at that the grid is disconnected from the system. Case 1.with PI controller

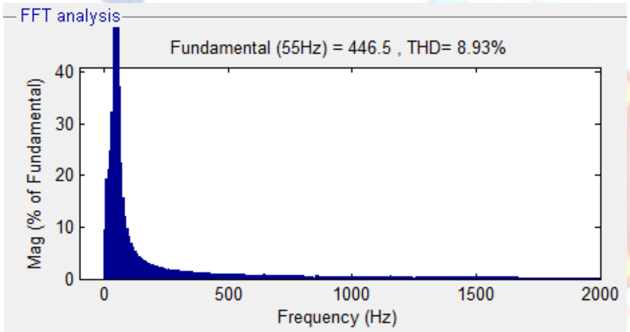


Fig12: shows the total harmonic distortion values under with PI controller.

IX. Conclusion

In this paper, a flexible ac distribution system device for microgrid applications has been presented. In this paper, the solution integrates EKF into the control design for frequency tracking and to extract the harmonic spectra of the grid voltage and the load currents. The device is installed at the PCC that the microgrid and other electrical networks are connected to and is designed to tackle a wide range of PQ issues. It also operates as a DG unit to perform load sharing when the cost of generation from the grid is high such that peak shaving is achieved and also during islanded operation of the microgrid. The conclusion is device can handle a wide range of PQ issues, thus increasing the overall PQ and reliability of the microgrid. However, the proposed design concept still needs further validation by experimental studies because measurement errors due to inaccuracies of the voltage and current sensors, and modeling errors due to variations in system parameters could affect the performance of the device in practical implementation. The security enhancement of multiple distributed generation (DG) by the harmonized grouping.

References

[1] F.Wang, J. L.Duarte, and M.A.M. Hendrix, "Grid-Interfacing Converter Systems with Enhanced Voltage Quality for Microgrid Application Concept and Implementation" IEEE 2011. Volume: 26, Issue: 12

[2] F.Wang, J.L.Duarte, and M.A.M.Hendrix, “Pliant active and reactive power control for grid-interactive converters under unbalanced voltage dips,” IEEE Transactions on Power Electronics, in press, 2010. Volume: 26, Issue: 5.

[3] H.Farhangi, “The path of the smart grid,” IEEE Power Energy Mag.,vol. 8, no. 1, pp. 18-28, Jan./Feb. 2010

[4] H.Fujita, and H.Akagi, “The unified power quality conditioner: the integration of series- and shunt-active filters,” IEEE Trans. Power Electron., vol. 13, no. 2, pp. 315-322, Mar. 1998

[5] S.Silva, P.F.Donoso-Garcia, P.C.Cortizo, and P.F.Seixas, “A three phase line-interactive ups system implementation with series-parallel active power-line conditioning capabilities,” IEEE Trans. Ind. Appl., vol. 38, no. 6, pp. 1581-1590, Nov./Dec. 2002.

[6] B.Han, B.Bae, H.Kim, and S.Baek, “Combined operation of unified power-quality conditioner with distributed generation,” IEEE Trans. Power Delivery, vol. 21, no. 1, pp. 330-338, Jan. 2006.

[7] H.Tao, “Integration of sustainable energy sources through power electronic converters in small distributed electricity generation systems,” PhD dissertation, Eindhoven university of technology, 2008.

[8] J.M.Guerrero, L.G.D.Vicuna, J.Matas, M.Castilla, and J.Miret, “A wireless controller to enhance dynamic performance of parallel inverters in distributed generation systems,” IEEE Trans. Power Electron., vol. 19, no. 5, pp. 1205-1213, Sept. 2004.

[9] Y.W.Li, and C.-N.Kao, “An accurate power control strategies for power-electronic-interfaced distributed generation units operating in a low-voltage multi bus micro grid,” IEEE Trans. Power Electron., vol. 24, no. 12, pp. 2977-2988, Dec. 2009.

[10] F.Wang, J.LDuarte, and M.A.M.Hendrix, “Reconfiguring grid interfacing converters for power quality improvement,” in Proc. IEEE

Benelux Young Researchers Symposium \ in Electrical Power Engineering, 2008, pp. 1-6.

[11] Sungwoo Bae, Alexis Kwasinski "Dynamic Modeling and Operation Strategy for a Microgrid with Wind and Photovoltaic Resources" IEEE 2012 TRANSACTIONS ON SMART GRID Volume: 3, Issue: 4

[12] L.H.Tey, Member, IEEE, P.L.So, Senior Member, IEEE, and Y.C.Chu, Member, IEEE "Improvement of Power Quality Using Adaptive Shunt Active Filter"IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 20, NO. 2, APRIL2005.