

# PV and Renewable Energy Research/Training for Optimal Power Management and Distribution

James A.Momoh, Fellow,IEEE

Center for Energy Systems and Control (CESaC), Howard University, Washington DC 20059

## Abstract

The research being conducted in the area of Renewable Energy at Howard University continues to develop from its inception. This project is aims to develop a research infrastructure in Renewable Energy to prepare students and faculty in modeling, analysis and management of Photovoltaic/Renewable Energy to sustain U.S. National Economy. And also expose high school students in renewable Energy Research.

Previous work in this project resulted in the successful modeling of the PV which has formed the basis for the next step of the project, the development of a PV based management scheme for the optimal power dispatching of the PV system. Subsequent to this development the research mutated into an Intelligent Customer Power Management Scheme which utilized the PV as the renewable energy DG supply.

## Objectives

The main objective of this project is the development of a research infrastructure in Renewable Energy. This will function to prepare students and faculty in modeling analysis and management with respect to Photovoltaic / Renewable Energy to sustain the U.S. National Economy.

Additionally, the objectives of the research are to develop an optimal structure for a renewable-energy based power system that operates optimally given changes in power output.

## Technical Approach

There are two approaches to development of construction and modeling namely base on construction and network. The modeling is briefly discussed as follows:

### PV Modeling for Power Management Studies

Three PV models (simplified, two-stage and three stage models) are compared for complexity, which directly impact the costs of production models of PV. The following are the mathematical models of PV evaluated:

$$I = I_{ph} - I_D = I_{ph} - I_s \left( \exp\left(\frac{V}{mV_T}\right) - 1 \right)$$

$$I_{ph} - I_s \left( \exp\left(\frac{V + IR_s}{mV_T}\right) - 1 \right) - \frac{V + IR_s}{R_p} - I = 0 \quad (1)$$

$$0 = I_{ph} - I_{s1} \left( \exp\left(\frac{V + IR_s}{m_1 V_T}\right) - 1 \right) - I_{s2} \left( \exp\left(\frac{V + IR_s}{m_2 V_T}\right) - 1 \right) - \frac{V + IR_s}{R_p} - I - a(V + IR_s) \left( 1 - \frac{V + IR_s}{V_{Br}} \right)^{-n}$$

Where:  $V_T$  : Thermal Voltage given by  $V_T = KT / q$

$V_{PV}$  : Operating voltage of the cell

$I_{PV}$  : Operating current of the cell

$I_S$  : Reverse saturation current of the cell

$I_L$  : Photo Current

$I_D$  : Diode current

$q$  : Charge of electron

$K$  : Boltzman's constant

$T$  : Absolute Temperature

$a$  : Diode ideally factor

With the completion of a PV Modeling Approach for Power Management Studies, this model has been utilized in the development of an Intelligent Customer Distribution Managements System. The ICDMS designed was tested and found applicability for power network models with and without DG (PV, wind, fuel cell). Achieving this goal required that factors which would be indicators of impending irregularity in the power supply or its quality be identified. These factors are to be presented in the form of the following indices: power quality, voltage sag and power factor.

### Intelligent Customer Distribution Management System

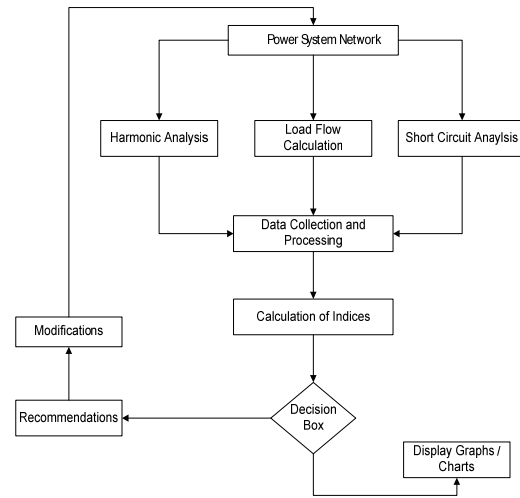


Figure 1: Flowchart for Methodology for the Processing Scheme as formulated for the ICDMS.

An integrated design of the Intelligent Customer Distribution management System has been developed. It includes power network models which are simulated with

and without DG (PV, wind, fuel cell). The Renewable Energy sources are modeled appropriately to determine whether they are real or reactive or combination sources. Load flow is simulated to get the voltage and current flows, and losses of the system. Using the information, the power Quality indices (Total Harmonic Distortion (THD), voltage sag, power factor) were determined.

The development of these indices requires numerical analysis. On comparison of these values to IEEE and other operating standards, measures are to be formulated to maintain or promote values which lie within the pre-determined thresholds. Due to the dynamism of the current de-regulated power environment, this management system will provide suggestions with specificity ensuring that consumers have the opportunity to make the best decision for themselves and the network.

- Determination of contingencies / suggestions for rectification
- Display to user necessary information for the user to make decisions to rectify impending problem.
- Modification of network based on consumer's decision – signaling is to be conducted by the management system relative to the user's feedback which would actuate the rectification method selected.
- Price signaling / reward to consumer to motivate participation recompense is suggested for the users for their participation, in much the same way as other customer oriented schemes such as "time-of-use pricing."

As an additional factor, consideration for the versatility of customer loads and how they vary from their original design has been introduced. This resulted in the decision to further investigation on networks which were first established many years ago, but which have been modified / altered as customers' needs develop. The impact that the introduction of PV/ Renewable Energy DGs would have on such networks was of particular concern.

For the determination of the impact the use of PV/Renewable Energy DGs have on networks which have undergone much addition in terms of loads over several years, a seven(7) bus network previously used in this research was utilized. This system was analyzed and was utilized as the initial state of the network and load flow in PSAT conducted to determine the trends in power flow as well as voltage levels in the determination of voltage sag. Under varying fault conditions and contingencies the network was analyzed to establish the conditions for voltage sag.

The following network shown in Figure 1 was utilized as the initial network.

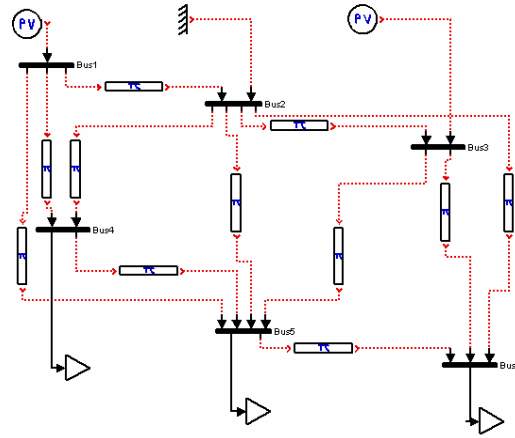


Figure 2: Initial seven (7) bus network

## Results and Accomplishments

For the design of the methodology, a 30-bus network was utilized with and without PV. Simulations were conducted under fault conditions. The overall power quality index was produced as a composite based on harmonics, power factor and voltage sag.

Sensitivity studies identified voltage (i.e. voltage sag and power quality) for the systems quality indices.

The load flow analysis of the 7-bus network in Fig 2 resulted in several conclusions which can be seen to impact on the design of the Management system. Initial analysis has revealed that the increase of load for given network to the order of 2 times the original load results in a drop in the voltage at the load buses 4,5 and 6.

## Conclusion

The research to be continued with the implementation of the intelligent power management system for use on the customer's side of the grid. This will consist of expanding rule base to accommodate DG disconnection if initial system has been restored and Implementation of Rule base with VP expert system This also consists of some additional Features which includes Minimization of power consumption, Circuit which converts DC power generated by the PV panel into AC for use in home. Circuit which stores energy generated in the day time for use at night, Switching system to tie the grid to the PV supply and tracking the sun will increase the energy output of the array.

Additionally the study of a test location is projected which would serve as a test bed, and aged network is favorable. The experimental acquisition of signatures at key locations in the building, followed by extraction using analysis is hoped to reveal conditions which necessarily must be incorporated in this design. The formulation and rigorous testing under conditions of harmonics etc. of a devised algorithm will be followed by the translation of this design into an intelligent system, utilizing a suitable microprocessor and I/O components.