

A Genetic Algorithm for the Definition of Nodal Load Time Evolutions in Micro Grids Assessment

Saman Korjani, Mario Porru, Alessandro Serpi, Alfonso Damiano
Department of Electrical and Electronic Engineering
University of Cagliari
Cagliari, Italy

Abstract— One of the on-going research topic in smart grid planning and assessment is the definition of suitable time evolution of load profiles in micro grids by using the information about the network topology and the available electrical measurements. This paper presents an approach for a heuristic definition of nodal load profiles in micro grids when the available measurements are not exhaustive for its state evaluation. In particular, in order to develop the preliminary micro grids assessment, a Genetic Algorithm (GA) has been employed to determine possible evolution of nodal load profiles that satisfy the power system constraints and input measurements. In order to verify the effectiveness of proposed methodology a real micro grid has been considered as case of study. The micro grid has been simulated in Digsilent and the used GA has been implemented in Matlab environment. Finally, Digsilent Programming Language (DPL) has been employed for interfacing the GA with Digsilent.

Keywords—Genetic algorithm, Micro grid assessment, Micro grid design, Nodal Load profiles.

I. INTRODUCTION

The evolution of load profile in micro grid is a very complex task when the exploitation of distributed generation occurs. However, load time evolutions in micro grids are fundamental quantities for planning and designing infrastructure enhancement and for the development of Energy Management System. Hence, the definition of nodal load profiles and their possible time evolutions into micro grids represent basic information for their assessment and design. However, the availability of time evolutions of electrical quantities is not always assured in distribution systems due to the necessity to install expensive smart meter or network power analyzer. In order to overcome these critical issues different methods to evaluate dynamically the state of networks and/or nodal loads are reported in the scientific literature. Load modeling and methods for its estimation have been described in [1]. Several approaches have been proposed to estimate loads such as existing diversified load curves [2] and distribution-state-estimation (DSE) [3][4]. Load profiles estimation on distribution feeder without any knowledge about the parameters of power systems has been proposed in [5][6].

However, the accuracy of these identification algorithms is strictly connected to the installation of measurement devices in specific points of the distribution network that depend on the

This activity has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646463.

topology of the power system. On the other hand, the preliminary assessment of a micro grid, aimed to evaluate its technical and economic potential does not require accurate information about the time evolution of nodal electrical quantities, especially if the measurements are not exhaustive for the coherent definition of load profiles in each node. In this context, the definition of an off-line algorithm based on power flow, which allows the determination of possible time evolution of the nodal loads that are consistent and coherent with the power system topology and constraints, can effectively support the designer in micro grid assessment, avoiding to resort to additional expensive measurements.

In this paper, the authors proposed the use of a computing methodology for defining the time evolution of nodal loads in a micro grid in presence of distributed generation. It has been performed resorting to a heuristic algorithm which is supported by power flow simulations used to check the power system constraints connected to the topology, to the devices installed and to the operative standard conditions of the analyzed power system. This research activity has been developed considering an analysis of actual technical literature that has put in evidence a limited effort in the nodal load estimation. Moreover, Genetic Algorithms (GAs) or optimization methods have not been considered for determining or for estimating nodal load yet.

Based on this consideration, a GA has been used in order to determine the time evolution of nodal loads in a distribution system characterized by the availability of electrical measurements just on the Point of Common Coupling (PCC). The overall goal is to find active power of loads on different buses for one day. Since the production and consumption in the power system has to match to each other instantaneously, the total active and reactive power consumption of loads as well as the losses must be equal to energy that is delivered to the PCC. In addition, the bus voltage and current of branches have to respect the operative standard constraints.

To perform the proposed methodology for defining the nodal loads a genetic algorithm in MATLAB has been used. GA determines optimal active power of nodal loads according to voltage and current limits and based on the given power flow value at the PCC in each time intervals. This is done by means of the Newton Raphson method implemented in Digsilent. Power Factory offers a selection of calculation methods, including a full AC Newton-Raphson technique

(balanced and unbalanced) and a linear DC method [7]. In particular, to be able to perform the proposed methodology the Matlab and Digsilent software platforms have been interfaced in order to benefit of the specific advantages of each software platform. The paper is structured as follows: in Section II the formulation used for the genetic algorithm implementation for nodal loads definition in a micro grid is reported; in Section III the case of study is described and finally in Section IV the results of load profiles definition have been presented and discussed.

II. LOAD PROFILE DEFINITION USING GENETIC ALGORITHM

A. Genetic Algorithm

The GA is an optimization method based on evolution adaptations in nature. The GA works with a population of individuals (chromosomes), in which each individual stands for a solution. A new generation is produced considering individuals fitness function and genetic operators (selection, crossover and mutation) and individual's fitness improve through the algorithm iterations [8]. This algorithm is used for power system optimization problems widely.

In this paper, a genetic algorithm is used for nodal load profile definition considering power system constraints. The initial population has been generated randomly considering an array of chromosomes in which each of them represents the active power of each bus [9]. In particular, the GA used for nodal load definition is reported in the flowchart shown in Fig. 1.

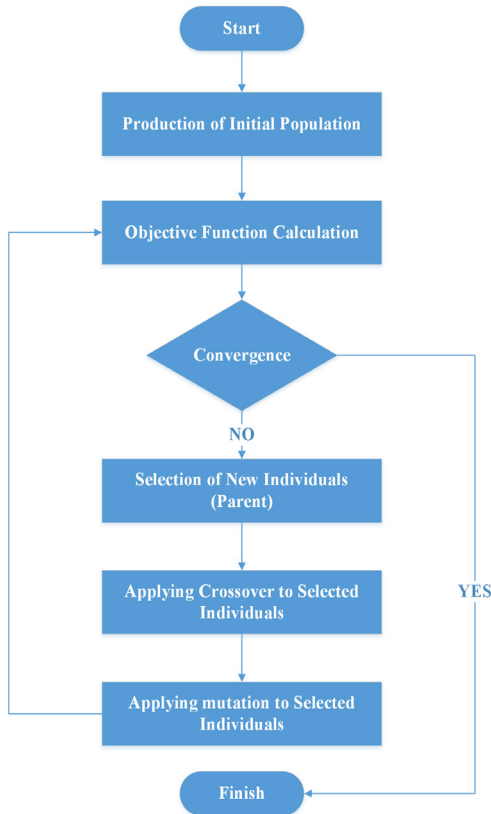


Fig. 1. Genetic algorithm flow chart.

B. Problem Formulation

Fitness function for determination of active power of loads in order to compare the power profiles at PCC is defined as below

$$F = \sum_{t=i}^{t=i+1} P_{PCC}^i - \sum_{t=i}^{t=i+1} P_{prod}^i - \sum_{t=i}^{t=i+1} P_{load}^i - \sum_{t=i}^{t=i+1} P_{loss}^i \quad (1)$$

where

$$\begin{aligned} P_{PCC} &= \text{Measured active power at PCC} \\ P_{prod} &= \text{Measured produced active power of DGs} \\ P_{load} &= \text{Load active power} \\ P_{loss} &= \text{Measured loss} \end{aligned}$$

The determination of initial values of active power for each load has been carried out by GA, which selects the values randomly in accordance with specific load constraint. Particularly, the range of each load active power can be defined as (2):

$$0 \leq P_{L_n}^i \leq P_{T_n}^{Nom} \quad (2)$$

Lower bounds of load powers are set to zero, while upper bounds can be considered as nominal active power of transformer of the loads ($P_{T_i}^{Nom}$). A mixed number of residential and commercial customers constitutes the typical load connected to each bus

$$\{P_{L_1}^i + P_{L_2}^i + P_{L_3}^i \dots + P_{L_n}^i\} = \sum_{t=i}^{t=i+1} P_{load}^i \quad (3)$$

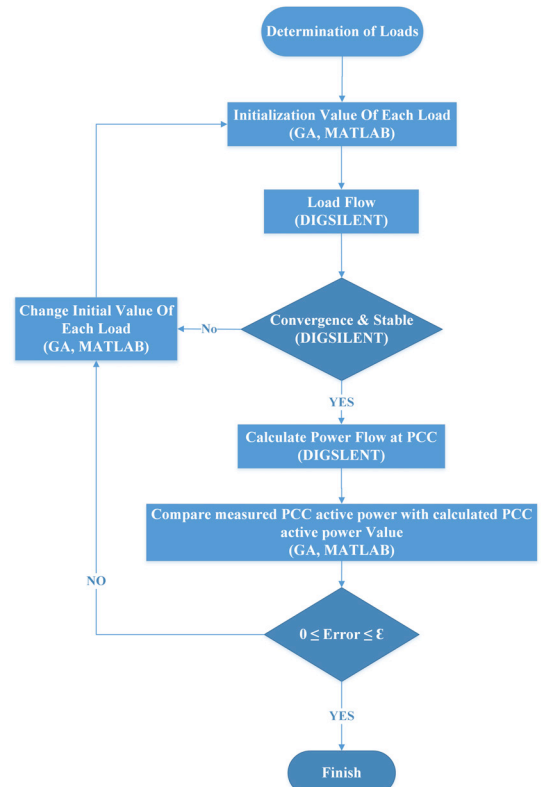


Fig. 2. Load profile definition flow chart

Interval (4) has been considered as constraint for voltage of buses in MV grid which the calculation is in per unit, also current constraint for lines of MV grid has been employed as (5) which I_T^i is the thermal current of each line.

$$0.95 \leq V_{Bus}^i \leq 1.05 \quad (4)$$

$$I_L^i \leq 1.2I_T^i \quad (5)$$

The following steps consist of getting the load active power at each node. These steps will be repeated for each time interval and it is continued until fitness function to be minimized. Consequently, the following procedure is carried out:

1. Initialization of load value by using GA in Matlab,
2. Load flow by using initial value: Newton Raphson in Digsilent has been employed to get load flow at PCC, whereas voltage constraint (V_{Bus}^i) of each bus and thermal current (I_T^i) of all lines have been considered;
3. Checking stability and convergence;
4. Transferring load flow of PCC to GA running in Matlab for comparison by using Digsilent Programming Language (DPL);
5. Checking if the fitness function is minimized or not, if the error is less than ϵ , the profiling have been completed. Otherwise, the step 1 to step 4 have to be repeated,

Fig. 2. illustrates a summary of above mentioned steps.

III. CASE OF STUDY

In this paper, it is thus assumed that the power system is working in stable condition and that the steady state power flow calculation can be provided for each time interval [10]. Single line-diagram of the micro grid used as case of study has been shown in Fig. 3. It refers to the German island of Borkum, which is located in the North Sea and characterized by both conventional and RES power plants. In addition, the PCC consists of four submarine cables that enable a bidirectional power flow with the mainland.

The data related to topology of micro grid such as, transformers, lines, generation of distributed resources are known and they have been used to calculate power flow of system at PCC. Measured power flow at PCC and the amount of generation of each distributed resources for a day with 15 minutes time intervals are available. Particularly, Fig. 4 shows the measured production of the wind turbine and PV farm. The voltage level of the micro grid is 20 kV. The 35 nodal loads of micro grid have been profiled and these nodal loads are connected to medium voltage network, through 400V to 20 kV transformers whose main parameter is known. The voltage of buses, thermal current limitation of lines and power of transformers have been considered as the constraints in this study.

Digsilent power factory was selected to calculate the load flow in steady state mode for each time interval. For implementing the voltage and current constraint, Digsilent Programming Language (DPL) has been considered. Also, for interfacing GA of Matlab to Digsilent, DPL is used. By considering voltage and current constraints, contingency and stability of system has been provided.

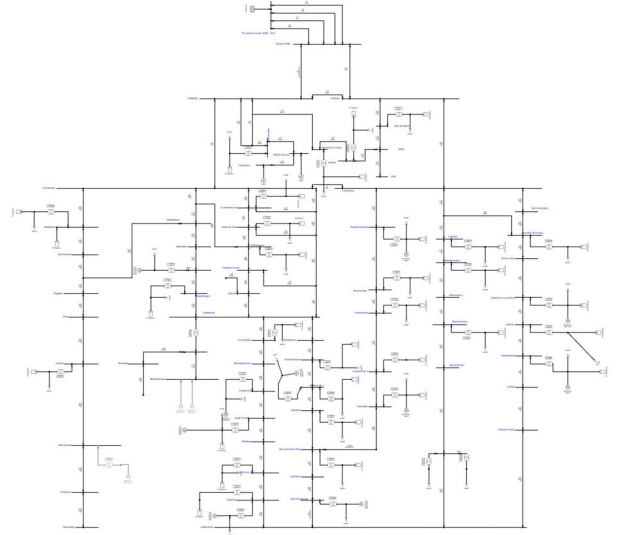


Fig. 3. Single-line diagram of the Micro grid used as case of study.

As the load profiles for each node is aggregated load, balanced load flow calculation has been employed for developing the GA described in Section II. For demand of reactive power of the microgrid and load, it has been assumed the main network provides the required reactive power. Hence the analysis is focused on the active power of loads which are determined referring to active power measured on the PCC.

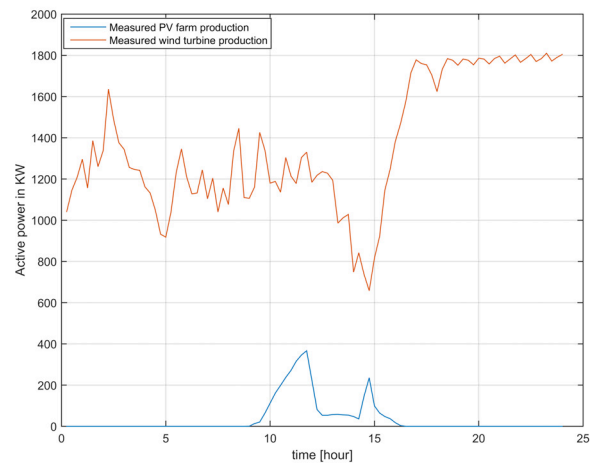


Fig. 4. Power production of Wind Turbine and PV farm

IV. RESULTS AND DISCUSSION

The results of 35 load profile are reported in this section. Fig. 5 shows measured active power of PCC and calculated active power of PCC with produced load profiles. These data have been taken from first day of January 2014. Nodal loads profile are shown from Fig. 6 to Fig. 12.

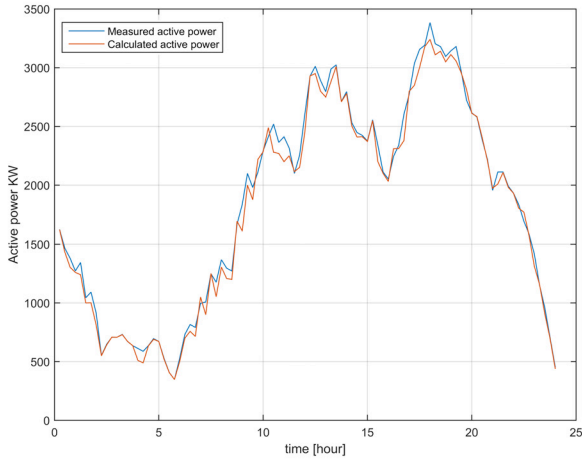


Fig. 5. Measured active power of PCC and calculated active power by load profiles

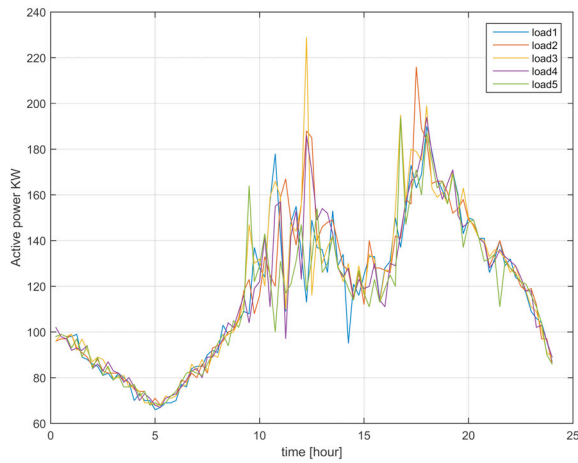


Fig. 6. Profile of load 1 to load 5 for one day

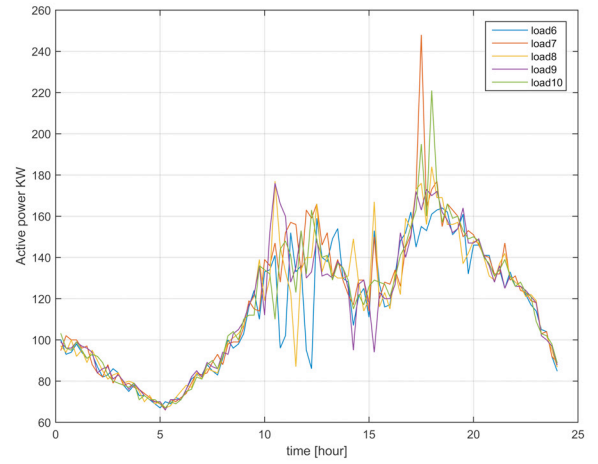


Fig. 7. Profile of load 6 to load 10 for one day

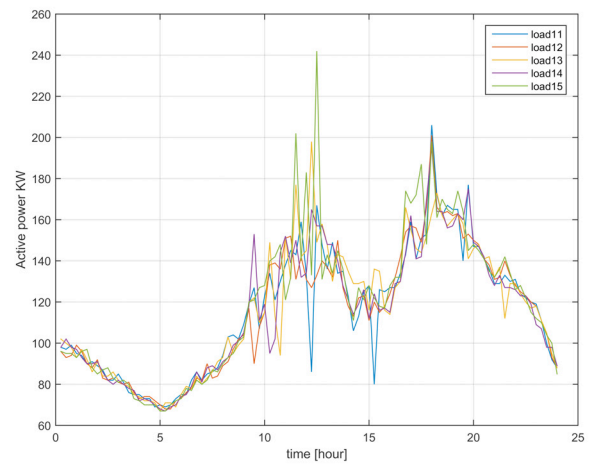


Fig. 8. Profile of load 11 to load 15 for one day

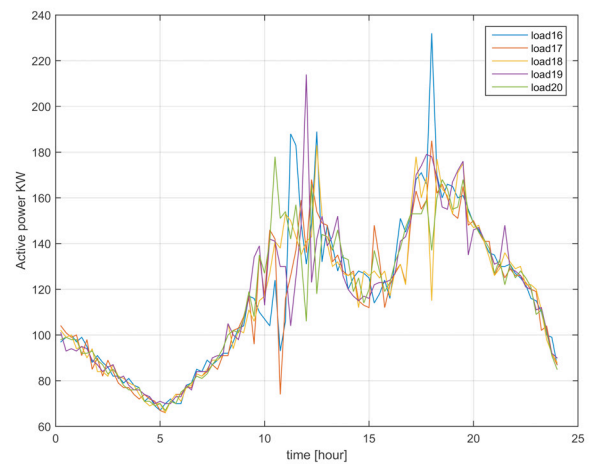


Fig. 9. Profile of load 16 to load 20 for one day

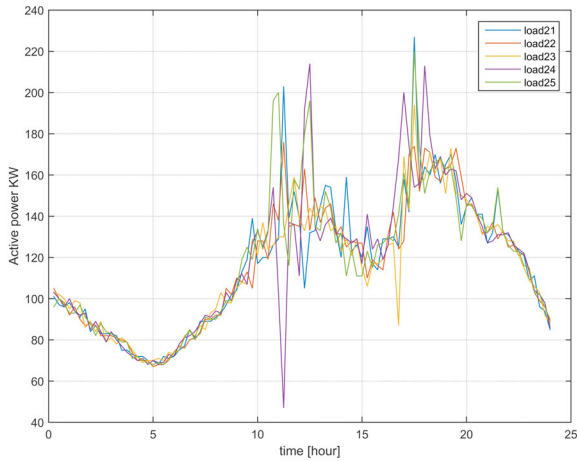


Fig. 10. Profile of load 21 to load 25 for one day

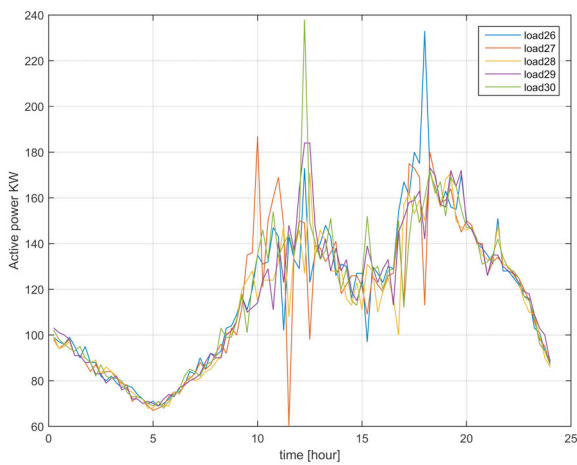


Fig. 11. Profile of load 26 to load 30 for one day

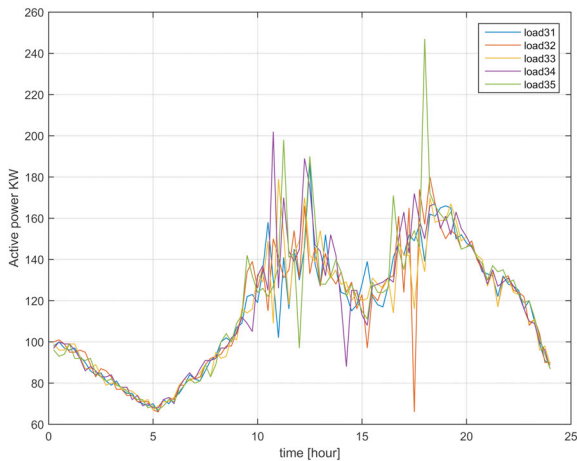


Fig. 12. Profile of load 31 to load 35 for one day

The histogram and kernel density distribution of voltage of buses in per unit for the day is shown in Fig. 13 which it highlights the excellent stability of the system during the implementation of the proposed method.

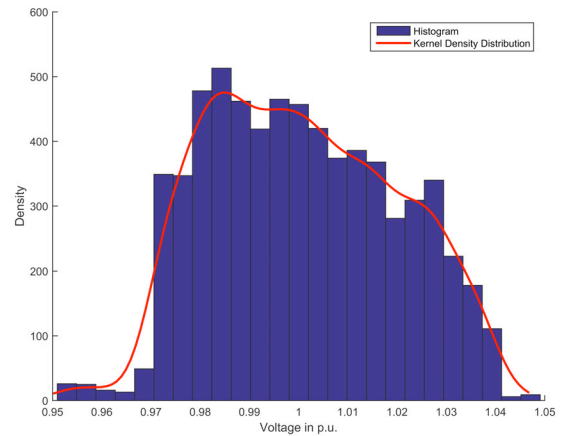


Fig. 13. Voltage Histogram of all buses of MV grid for all the every 15 minutes in p.u.

V. CONCLUSION

In this paper, a heuristic approach for defining the nodal load profile for micro grid assessment has been proposed. A Genetic Algorithm has been implemented to determine a feasible time evolution of nodal load in a micro grid characterised by a limited number of electrical quantity measurements. Digsilent has been used for power flow calculation in order to provide the information about the satisfaction of electrical and operative constraint of the microgrid. Then GA is done by MATLAB, which is used to produce load profiles at each load bus. Both software have been interfaced as closed loop by using DPL. The calculated load profiles are used to compute the power flow at PCC.

The proposed methodology has been simulated referring to a case of study. The simulation results highlight a very good matching with the given PCC profile. Much more details on the algorithm will be enclosed in the final version of the paper, as well as a detailed description of the micro grid considered in this paper.

REFERENCES

- [1] C. S. Chen, et al., "Application of load surveysystems to proper tariff design," Power Systems, Power Systems, IEEE Transactions on, vol. 12, 1997, pp. 1746-1751.
- [2] R. P. Broadwater, A. H. Khan, H. E. Shaalan, and R. E. Lee, "Time varying load analysis to reduce distribution losses through reconfiguration," IEEE Trans. Power Delivery, vol. 8, Jan. 1993, pp. 294-300.
- [3] M. E. Baran and A. W. Kelley, "State estimation for real-time monitoring of distribution systems," IEEE Trans. Power Syst., vol. 9, pp. 1601-1609, Aug. 1994. K. Young-II, et al., "Customer clustering and TDLP (typical daily load profile) generation using the clustering algorithm," in *Transmission & Distribution Conference & Exposition: Asia and Pacific, 2009,2009*, pp. 1-4.
- [4] T. Wang and M. Fan, "A novel load estimation method in distribution network," in *Proc. Power Syst. Technol.*, vol. 1.1, 1998, pp. 567-571.
- [5] M. M. Hussain, Z. H. Zakaria and S. Serwan, "FastICA techniques for load profiles estimation, " in *Industrial Electronics and Applications (ISIEA), 2012 IEEE Symposium on*, 2012, pp. 161-166.
- [6] M. M. Hussain, Z. H. Zakaria and S. Serwan, " Nodal Load Profiles Estimation for Time Series Load Flow Using Independent Component Analysis, " in *World Academy of Science, Engineering and Technology*

International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:6, No:12, 2012, pp 1437-1442.

- [7] http://www.digsilent.de/tl_files/digsilent/files/powerfactory/PowerFactory15/WhatsNew_PF150.pdfGary
- [8] F. Razavi, H. A. Abyaneh, M. Al-Dabbagh, R. Mohammadi, and H.Torkaman, "A new comprehensive genetic algorithm method for optimal overcurrent relays coordination," *Elect. Power Syst. Res.*, vol. 78, 2008, pp. 713–72.
- [9] R. L. Haupt, S. E. Haupt, "Practical Genetic Algorithms", Second Edition, John Wiley & Sons, Inc., Publication, 2004.
- [10] W.F. Tinney and C.E. Hart, "Power flow solution by Newton's method," *IEEE Trans. Power App. Syst.*, vol. PAS-86, Nov. 1967, pp. 1449–1460