

Online Voltage Estimation for Distribution Networks in Presence of Distributed Generation

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Abstract

This paper presents an Artificial Neural Network (ANN) model for online profile voltage estimation to aid distribution network voltage regulation with consideration of Distributed Generation (DG). Arrival of DG to the distribution network affects the feeder voltages. Commonly, the On-Load Tap Changer (OLTC) transformer with a line drop compensation (LDC) that monitors the voltage along the feeder is used to regulate the voltage within allowable limits. But with presence of DG because of multi-directional power flow, there are complications for the operation of the LDC to detect the correct amount of voltage profile along the feeder. The proposed estimation method employs Artificial Neural Network (ANN) concept and eliminates utilization of power flow calculations, resulting in low computational burden and online operation especially in case of systems with high order of complexity. Proposed technique is tested on a 13 bus distribution network and simulation outcomes validate effectiveness and efficiency of the suggested scheme.

Keywords: Artificial Neural Network (ANN), Distributed Generation, On-Load Tap Changer

1. Introduction

A Distributed Generation (DG) as, “an electric power generation source connected directly to the distribution network or on the customer side of the meter” has been defined¹. Voltage regulation in distribution systems is performed with the help of several voltage regulating devices, such as on-load tap changer (OLTC) and step voltage regulators. Previously, the distribution networks were considered to act without any DG. Arrival of DG to the distribution systems affects the voltages of feeder and also changes the power flow from unidirectional to multi-directional. On the other hand, solar and wind DGs, have uncertain output power and therefore as a result of these, fluctuations of the voltage profile¹⁻². When the voltage profile of the system is disturbed, the network should find that status and take adequate means to restore allowable voltage limit.

Commonly, the OLTC transformer with a LDC that monitors the voltage along the feeder is used to regulate the voltage within allowable limits. The OLTC can regulate voltage about $\pm 10\%$. But with presence of DG because of multi-directional power flow, there are complications for the operation of the LDC to detect the correct amount of voltage profile along the feeder. Indeed, it has become obvious more than any time that the adoption of smart grid is essential. The extension of the Smart Grid meets many challenges³. Some of the technical challenges are the need to new “smart” tools, like the Remote Terminal Units (RTU).

In ⁴, to find the optimal tap setting with the DG is formulated an optimization problem. In terms of real-time, this method cannot be feasible, as regards it is not potential to read the data of all the busses of the grid. In ⁵, a method was presented to authorize the voltage regulator controller to consider the effect of DG. Although, this

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design cannot deal with several DG on the same feeder. In ⁶ used a coordinated voltage control method to enable the determination of lowest and highest voltages of the feeder in the presence of DGs and to act the voltage regulator according to that. In ⁷, a local, intelligent and auto-adaptive voltage regulator for DG is proposed. This regulator is able to coordinate in real time the control of several DGs. In ⁸ for small scale synchronous generators with unbalanced loads used a fuzzy based digital automatic voltage regulator. In ⁹, a voltage control strategy is proposed for DG using the voltage control mode and the power factor control mode. In ¹⁰ used an optimization technique for coordinated voltage control in distribution networks using DG. In ¹¹ proposes an online voltage control strategy for a realistic distribution system containing a based renewable DG unit and other voltage regulating devices.

In this paper proposed a method is based on the ANN concepts to calculate online voltage for all busses. The first step is based locating a Remote Terminal Unit (RTUs) at each line capacitor and each DG. The ANN to be employed the voltage of RTUs as input of network. The outputs of the algorithm are the voltage magnitudes of all busses along feeders.

The paper is organized as follows: Section 2 provides Artificial Neural Network definition. Section 3 provides case studies, and Voltage Estimation and Result are represented in Section 4. Section 5 presents outlines conclusions.

2. Artificial Neural Network

A Multi-Layer Perceptron (MLP) is a feed forward artificial neural network model that maps sets of input data

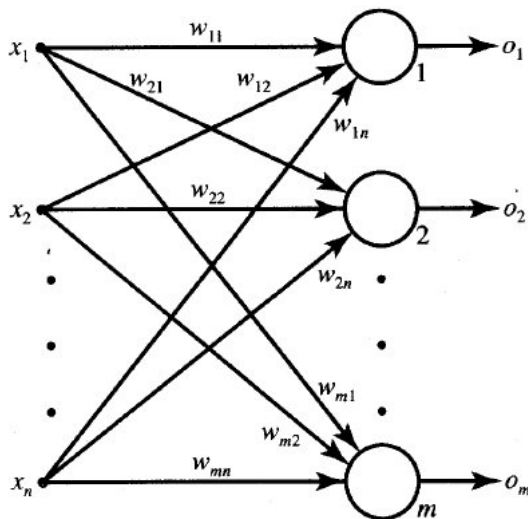


Figure 1. Feed forward network.

onto a category of suitable outputs as shown in Figure 1. Each node gathers all input nodes after multiplying each input value by a weight¹². A MLP contains of multiple layers of models in a directed graph, with each layer totally joined to the subsequent. Each node is a neuron with a nonlinear activation function but the input nodes not included¹³.

3. Case Study

The studied distribution network is a distribution system with the total load of 10536kW and 5992kVAR, 13 bus and 12 branches as it has been shown in Figure 1.

Table 1. Information of lines

Line	R(ohm)	X(ohm)
1-2	0.176	0.138
2-3	0.176	0.138
3-4	0.045	0.035
4-5	0.089	0.069
5-6	0.045	0.035
5-7	0.116	0.091
7-8	0.073	0.073
8-9	0.074	0.058
8-10	0.093	0.093
7-11	0.063	0.05
11-12	0.068	0.053
7-13	0.062	0.053

Table 2. Information of buses

Bus Number	P(KW)	Q(KVAR)
1	0	0
2	890	468
3	628	470
4	1112	764
5	1638	1378
6	474	344
7	1342	1078
8	920	292
9	766	498
10	1662	480
11	690	186
12	1292	554
13	1124	1480

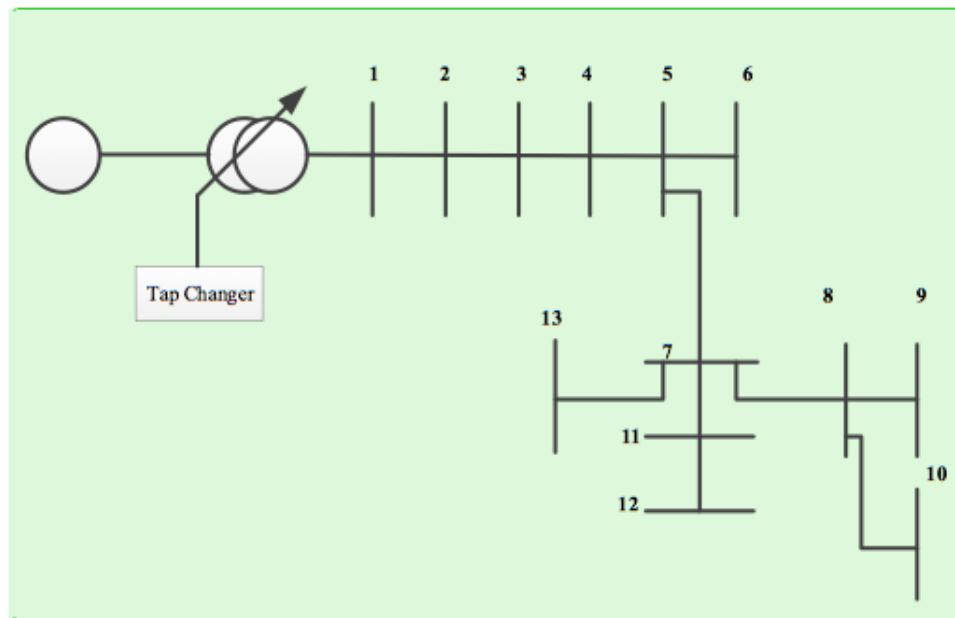


Figure 2. Single line diagram of the case study system.

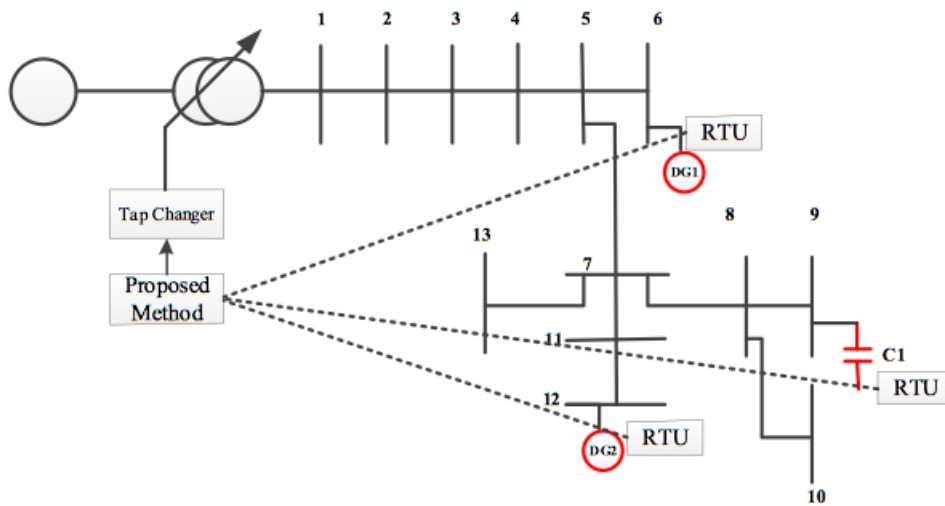


Figure 3. Locating a RTUs each line capacitor and at each DG Bus.

Bus and line information of 13-bus test system are listed in Tables 1 and 2, respectively.

This 13-bus test system 63/20kV has obtained from Khoda-Bande-Loo Substation of Tehran distributed network14.

4. Voltage Estimation and Result

The scheme of voltage control offered in this paper is intended to be utilized as an online function, for online voltage approximation. Hence, and in order to accelerate the voltage control algorithm, an ANN capable to mimic the behavior of the network (or micro grid) was included. This option empowered the utilization of the meta-heuristic algorithm employed in real-time operation, decreasing the Long times to simulate that were needed until compute successive network power flows. In point of fact, the ANN is utilized to prepare a steady-state equivalent of the grid, avoiding in this way the spread of the load flow analysis to the distribution level. In this paper proposes a technique is utilized the ANN concepts. The first step is based locating a RTU at each DG bus and each line capacitor (Figure 3). ANN to be employed the voltage of RTUs as input of network. The outputs of the algorithm are the voltage magnitudes of nodes along feeders. The RTU is a device for getting and transmitting information about voltages to a master system.

To get a good implementation, various ANN topologies that in a number of layers and neurons in each hidden layer are different, were examined. The ANN with 3 inputs, 2 hidden layer has best efficiency. To train the

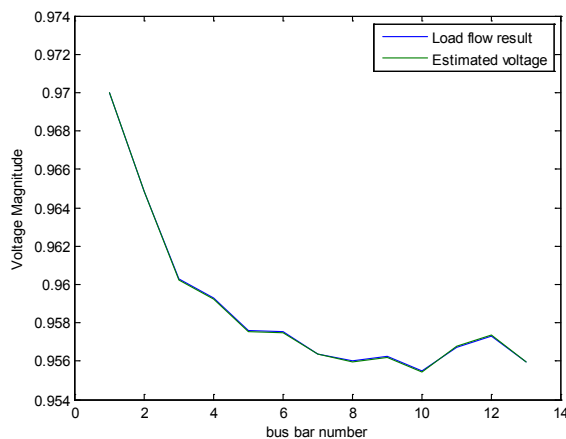


Figure 4. Load flow algorithm versus voltage profile obtained from the proposed method.

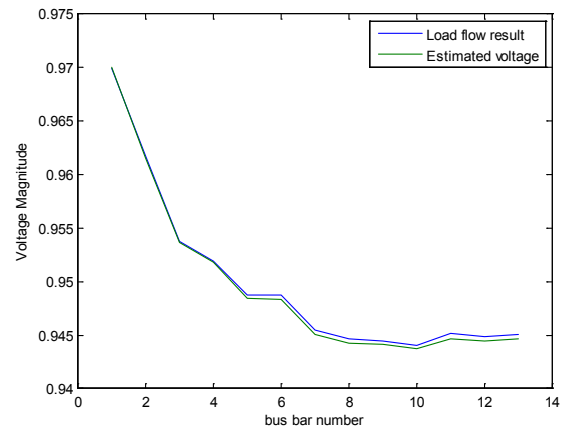


Figure 5. Load flow algorithm versus voltage profile obtained from the proposed method.

ANN need to produce the data collection corresponding to the inputs elected, therefore a great number of power flows were calculated, considering various combinations of the inputs in order to determine the voltage profiles in each scenario. The MATLAB Neural Network Toolbox using the Levenberg–Marquardt algorithm was used to identify the ANN parameters. Notwithstanding the unpretentious structure adapted for the ANN, the performance parameters shown the quality of the scheme to simulate the behavior of the grid. However, in case of grid reconfiguration, for example to add a new DG, a new ANN should be calculated. To wit, that it is essential to update and improve the data for the power flow and then produce a new data collection and train a new ANN that mimics the grid behavior. A large number of load patterns are generated randomly by perturbing the load at all the buses and generation at the micro generator buses.

In order to assess validity of proposed model for voltage estimation along micro grid feeders, two different scenario are considered.

4.1 First Scenario

At the first scenario, it is assumed that the capacitor banks at bus 9 can inject reactive power of 2.5p.u and DG1&2 at bus 6 and bus 12 can inject 0.1 p.u and 5p.u, respectively. After running Algorithm voltage profile generated from load flow algorithm versus voltage profile obtained from the proposed procedure as shown in Figure 4.

4.2 The Second Scenario

At the first scenario, it is assumed that the capacitor banks at bus 9 can inject reactive power of 9p.u and DG1&2 at bus 6 and bus 12 can inject 6 p.u and 12 p.u, respectively. After running Algorithm voltage profile generated from load flow algorithm versus voltage profile obtained from the proposed method as shown in Figure 5.

5. Conclusion

The main aim of this paper was to develop a novel online voltage estimation method for the distribution systems in the presence of smart grid. As was seen with the use of RTUs that were put on the specific buses, the information of these buses through a communication channel sent to a central computer. Here, there is an estimation voltage algorithm based on ANN that calculate voltage profile with high accuracy. Then, the calculated values sent to a master system to aim regulate tap setting of OLTC in order to modify the voltage profile.

6. References

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