Location of Single Line-to-Ground Faults on Distribution Feeders Using Voltage Measurements

R. A. F. Pereira, *Student Member, IEEE*, L. G. W. da Silva, M. Kezunovic, *Fellow*, *IEEE*, and J. R. S. Mantovani, *Member, IEEE*

***Abstract*-- This paper proposes a dedicated algorithm for location of single line-to-ground faults in distribution systems. The proposed algorithm uses voltage and current phasors measured at the substation level, voltage magnitudes measured at some buses of the feeder, a database containing electrical, operational and topological parameters of the distribution networks, and fault simulation. Voltage measurements can be obtained using power quality devices already installed on the feeders or using voltage measurement devices dedicated for fault location. Using the proposed algorithm, likely faulted points that are located on feeder laterals geographically far from the actual faulted point are excluded from the results. Assessment of the algorithm efficiency was carried out using a 238 buses real-life distribution feeder. The results show that the proposed algorithm is robust for performing fast and efficient fault location for sustained single line-to-ground faults requiring less than 5% of the feeder buses to be covered by voltage measurement devices.**

***Index Terms*-- Fault Location, Power Distribution, Voltage Measurement.**

I. Introduction

In the recent past, electric power regulatory agencies have increased the requirements for electric utilities to maintain electric power supply indices within quality standards. One way of attending to these requirements is carrying out fault location in an efficient way decreasing the customer outage time. As a consequence, techniques, algorithms and methodologies for fault location have received significant attention of researchers. The main differences found among various proposals for fault location on distribution feeders are related to the number of used measurement variables and required instrumentation, as well as the approach for finding fault location.

Algorithms, methodologies and techniques for fault location utilizing measurements of voltage and current phasors of fundamental frequencies at the sending node of the feeder or at the substation, as well as the derived equations using symmetrical components, suitable load modeling, and even fault indicators installed on the feeders were proposed in [1]-[5]. Reference [6] proposes an association of fault indicators installed along the feeder, fault distance computation, statistical indication of frequency of fault occurrences on a line section, and probabilistic analysis to carry out fault location. Reference [7] presents an approach based on superimposed components of voltage and current phasors measured at the sending node of the feeder, derived phase-domain equations and, as well as the suitable load model. Fault location algorithms that use voltage and current phasors measured at the sending node of the feeder at the substation were presented in [8]-[10]. Loads are modeled considering their voltage dependence and phase-domain equations were derived, which enables the algorithms to be applicable for feeders composed of double and single-phase laterals. Additional analysis for selecting the most likely fault location among the fault locations candidates was also proposed. Reference [11] presents a method for fault location that uses fault indicators installed along the feeder and fuzzy logic to model the information from these devices. In [12] a technique using voltage and current measurements at the sending and receiving nodes of each line section of the feeder was presented. In this way, it is possible to locate the faulted section very accurately. Reference [13] presents a fault location methodology that combines a power systems analysis program along with database search method and pattern recognition technique. This methodology locates the faulted point by means of matching the measured voltage at the sending node of a substation with voltages for the same point calculated using fault simulations for each feeder node. Results are presented for location of faults involving zero resistance.

This paper presents a technique for fault location on overhead distribution feeders using measurements of pre- and during-fault voltage and current phasors at the sending node of a substation along with during-fault voltage measurements at the nodes along the feeder. The proposed technique was tested on an overhead, 13.8 kV, 238 nodes real-life feeder and the results show that this technique is robust and efficient for carrying out fault location in a fast and accurate way.

This work was supported in part by the CAPES (grant BEX0769/05-3), FEPISA (grant 007/2005) and CNPq.

R. A. F. Pereira is with Electrical Engineering Department – FEIS/UNESP, Ilha Solteira, Sao Paulo, Brazil (e-mail: ddigo@yahoo.com).

L. G. W. da Silva is with Electrical Engineering Department – FEIS/UNESP, Ilha Solteira, Sao Paulo, Brazil (e-mail: lgwesz@gmail.com).

M. Kezunovic is with Electrical and Computer Engineering Department – Texas A&M University, College Station, Texas, USA (e-mail: kezunov@ece.tamu.edu).

J. R. S. Mantovani is with Electrical Engineering Department – FEIS/UNESP, Ilha Solteira, Sao Paulo, Brazil (e-mail: mant@dee.feis.unesp.br).

II. Fault Location Technique Using Voltage Measurements

Fault location on transmission lines based on comparison of measurements and simulations of both voltages and currents was proposed in [14]. Similar approach for fault location on distribution feeders was presented in [15]. This approach uses pre- and during-fault voltage and current phasors measured at the sending node of the feeder; during-fault voltage magnitudes measured at some feeder nodes, and derived equations using symmetrical components. In order for the proposed technique to be applicable for the three-phase untransposed feeders containing double and single-phase lateral branches, all equations that were derived using symmetrical components were replaced by phase-domain equations. Fig. 1 depicts the data flow in the technique proposed in this paper.

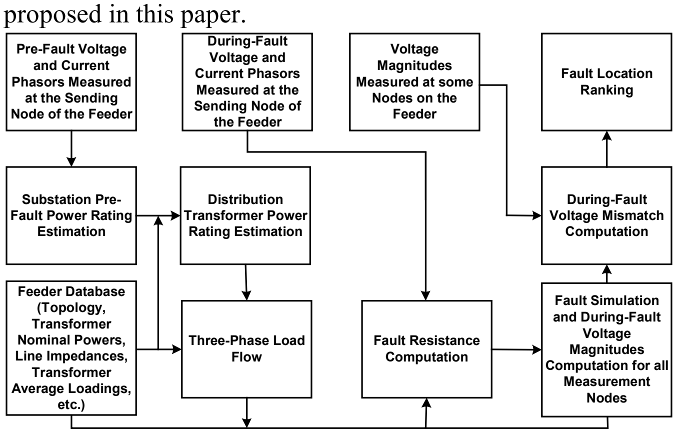

Fig. 1 Data flow in the proposed technique.

Following are derivations of the algorithm proposed for location of single line-to-ground faults.

A. *Measurements at the Substation*

Pre- and during-fault voltage and current phasors measurements at the substation are obtained from intelligent Electronic Devices (IEDs) placed on each feeder. IEDs can measure and store the necessary quantities for carrying out fault location. In order to extract voltage and current phasors of fundamental frequency from the signals sampled by IEDs, Discrete Fourier Transform for one-cycle data window is used.

B. *Measurements along the feeder*

During-fault magnitudes are measured at some feeder nodes using voltage measurement devices dedicated only for fault location purposes or using power quality devices already installed on the feeder. Fault location accuracy depends on where the voltage measurement devices are placed on the feeder. An optimization strategy for placement of voltage measurement devices using genetic algorithm is presented in [16]. Communication channels should be available for sending the measured data from remote feeder nodes to the computer responsible for processing the fault location algorithm. Voltage magnitudes are the *rms* values calculated by means of equation (1) for one-cycle data window.

$$V_{RMS} = \sqrt{\frac{1}{n}\sum_{i=0}^{n-1} v_i^2} \qquad (1)$$

where:

v_i: voltage instantaneous value;

n: number of samples in one-cycle data window.

C. *Substation Pre-Fault Power Rating Estimation*

Pre-fault voltage and current phasors measured at the substation level are used for estimating pre-fault power rating at the substation. This is an estimation of the pre-fault power rating at the substation because the measured power at this point contains the total losses along the feeder. The larger the losses of the feeder, the larger is the effect on the accuracy of the fault location process.

D. *Distribution Transformer Power Rating Estimation*

One of the sources of the fault location algorithm errors is the difficulty in estimating an exact loading of each transformer during fault events. In this paper, loading for each distribution transformer of the feeder is based on its nominal power rating stored in a distribution system database, substation pre-fault power rating, and average loading (β) estimated taking into account electric bills of each customer supplied by the transformer. Thus, the complex power rating for each transformer can be calculated using the following equation:

$$\mathbf{S}_i = \left(\beta_i S_i^{Nom} \cdot \frac{S_{Meas}^{SS}}{\sum_{k=1}^{nl} \beta_k S_k^{Nom}} \right) \cdot \left[\cos(\varphi_{SS}) + j\sin(\varphi_{SS}) \right] \qquad (2)$$

where:

S_i^{Nom} : Transformer nominal apparent power rating;

S_{Meas}^{SS}: Apparent power rating measured at the substation;

$\cos(\varphi_{SS})$: Power factor for the measured power rating at the substation;

nl: Total number of transformers supplying the feeder;

β_i: Average loading of the transformer i.

E. *Load Flow*

In this work, load flow is calculated using ATP program, and the load model is one with a constant impedance.

F. *Fault Resistance Computation*

Differently from the methodologies proposed in [8]-[10] for each investigated node, a fault resistance value should be calculated.

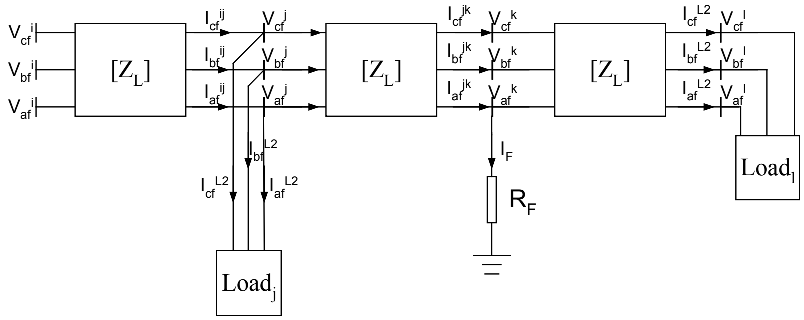

Fig. 2 Three-phase model of the distribution network.

Fig. 2 depicts a generic three-phase distribution feeder. Considering node i is the substation sending node, fault resistance value can be computed according to the following steps:

i) Starting from the sending node at the substation, during-fault voltage for node j is calculated using the following equation;

$$\begin{bmatrix} \mathbf{V}_{af}^{j} \\ \mathbf{V}_{bf}^{j} \\ \mathbf{V}_{cf} \end{bmatrix} = \begin{bmatrix} \mathbf{V}_{af}^{i} \\ \mathbf{V}_{bf}^{i} \\ \mathbf{V}_{cf}^{i} \end{bmatrix} - \begin{bmatrix} \mathbf{Z}_{aa} & \mathbf{Z}_{ab} & \mathbf{Z}_{ac} \\ \mathbf{Z}_{ab} & \mathbf{Z}_{bb} & \mathbf{Z}_{bc} \\ \mathbf{Z}_{ac} & \mathbf{Z}_{bc} & \mathbf{Z}_{cc} \end{bmatrix} \cdot \begin{bmatrix} \mathbf{I}_{af}^{ij} \\ \mathbf{I}_{bf}^{ij} \\ \mathbf{I}_{cf}^{ij} \end{bmatrix} \quad (3)$$

where:

$\mathbf{V}_{\alpha f}^{j}$: During-fault voltage on phase α at node j;

$\mathbf{Z}_{\alpha\alpha}$: Self-impedance of phase α of the line section;

$\mathbf{Z}_{\alpha\varepsilon}$: Mutual-impedance between phase α and ε;

$\mathbf{I}_{\alpha f}^{ij}$: During-fault current on the line section between nodes i and j.

ii) Using computed voltages for node j and considering constant impedance load model, load current $\mathbf{I}_{abc}^{L_j}$ is updated for fault condition by means of the following equation;

$$\begin{bmatrix} \mathbf{I}_{af}^{L_j} \\ \mathbf{I}_{bf}^{L_j} \\ \mathbf{I}_{cf}^{L_j} \end{bmatrix} = \begin{bmatrix} \frac{\mathbf{V}_{af}^{j}}{\mathbf{V}_{a}^{j}} \mathbf{I}_{a}^{L_j} \\ \frac{\mathbf{V}_{bf}^{j}}{\mathbf{V}_{b}^{j}} \mathbf{I}_{b}^{L_j} \\ \frac{\mathbf{V}_{cf}^{j}}{\mathbf{V}_{c}^{j}} \mathbf{I}_{c}^{L_j} \end{bmatrix} \quad (4)$$

where:

$\mathbf{V}_{\alpha}^{j}$: Pre-fault voltage on phase α at the node j;

$\mathbf{I}_{\alpha}^{L_\gamma}$: Pre-fault current on phase α of the load L_γ;

$\mathbf{I}_{\alpha f}^{L_\gamma}$: During-fault current on phase α of the load L_γ.

iii) Taking into account fault occurrence at the node j, during-fault current through branch jk is computed using the following equation;

$$\begin{bmatrix} \mathbf{I}_{af}^{jk} \\ \mathbf{I}_{bf}^{jk} \\ \mathbf{I}_{cf}^{jk} \end{bmatrix} = \begin{bmatrix} \frac{\mathbf{V}_{af}^{j}}{\mathbf{V}_{a}^{j}} \mathbf{I}_{a}^{jk} \\ \frac{\mathbf{V}_{bf}^{j}}{\mathbf{V}_{b}^{j}} \mathbf{I}_{b}^{jk} \\ \frac{\mathbf{V}_{cf}^{j}}{\mathbf{V}_{c}^{j}} \mathbf{I}_{c}^{jk} \end{bmatrix} \quad (5)$$

where:

$\mathbf{I}_{\alpha}^{jk}$: Pre-fault current on phase α of the line section jk;

$\mathbf{I}_{\alpha f}^{jk}$: During-fault current on phase α of the line section jk.

iv) After load currents connected at the node j and downstream branch currents of the node j have been updated single line-to-ground fault current to the node j is computed using the following equation;

$$\mathbf{I}_{\alpha f} = \mathbf{I}_{\alpha f}^{ij} - \sum_{n\in\Phi} \mathbf{I}_{\alpha f}^{L_n} - \sum_{m\in\Psi} \mathbf{I}_{\alpha f}^{m} \quad (6)$$

where:

α: Faulted phase;

m: Downstream branch of the node j;

n: Load connected at the node j;

Φ: Set of all loads connected at node j;

Ψ: Set of all branches connected downstream of node j.

v) Fault resistance for node j is computed by means of the following equation;

$$R_f^j = \mathrm{Re}\left\{ \frac{\mathbf{V}_{\alpha f}^{j}}{\mathbf{I}_{\alpha f}} \right\} \quad (7)$$

vi) Now, considering that the fault did not occur at the node j, and taking into account that the fault occurred at the node k, during-fault current through branch jk should be updated according to the following equation;

$$\begin{bmatrix} \mathbf{I}_{af}^{jk} \\ \mathbf{I}_{bf}^{jk} \\ \mathbf{I}_{cf}^{jk} \end{bmatrix} = \begin{bmatrix} \mathbf{I}_{af}^{ij} \\ \mathbf{I}_{bf}^{ij} \\ \mathbf{I}_{cf}^{ij} \end{bmatrix} - \begin{bmatrix} \sum_{n\in\Phi} \mathbf{I}_{af}^{L_n} \\ \sum_{n\in\Phi} \mathbf{I}_{bf}^{L_n} \\ \sum_{n\in\Phi} \mathbf{I}_{cf}^{L_n} \end{bmatrix} - \begin{bmatrix} \frac{\mathbf{V}_{af}^{j}}{\mathbf{V}_{a}^{j}} \sum_{m\in\Omega} \mathbf{I}_{a}^{m} \\ \frac{\mathbf{V}_{bf}^{j}}{\mathbf{V}_{b}^{j}} \sum_{m\in\Omega} \mathbf{I}_{b}^{m} \\ \frac{\mathbf{V}_{cf}^{j}}{\mathbf{V}_{c}^{j}} \sum_{m\in\Omega} \mathbf{I}_{c}^{m} \end{bmatrix} \quad (8)$$

where:

Ω: Set of branches connected downstream at the node *j*, excluding the branch *jk*.

vii) Return to the step *i)* and the same procedure is executed until one fault resistance value is computed for each feeder node.

h) Fault Simulation and Voltage Computation for measurement nodes: Analogously to the load flow, fault simulation is carried out using ATP program. During-fault voltages for the measurement nodes are computed and stored during fault simulation process.

i) Computation of during-fault voltage mismatches between measured and calculated voltages for each measurement node: Using measured and calculated voltages for each measurement node the during-fault voltage mismatches can be computed using the following equation:

$$\delta_i = \left| V^{i}_{meas} - V^{i,j}_{calc} \right| \qquad (9)$$

where:

V^{i}_{meas}: Voltage magnitude measured at node *i*;

$V^{i,j}_{calc}$: Voltage magnitude calculated for node *i* considering fault at node *j*.

j) Selection of the likely fault location: Likely fault location is selected based on the analysis of the values of δ_i for all measurement nodes. The values of δ_i for the faulted node should have the same magnitude. Then, selection of the likely fault location node is done using the following equation:

$$fb = \min_j \{\max\{\delta_i\} - \min\{\delta_i\}\}$$
$$i = 1,\ldots,nm \qquad (10)$$
$$j = 1,\ldots,nb$$

where:

nm: Total number of voltage measurement devices;

nb: Total number of feeder nodes.

III. Tests Results

The proposed technique for location of single line-to-ground faults was tested on an overhead, 13.8 kV, 238 nodes, real-life distribution feeder shown in fig. 3. Fault simulations were carried out using ATP program. Loads were modeled as constant impedances and average loading of each distribution transformer (β), varying between 0.90 and 1.10, was estimated based on electric bills of each customer connected to the transformer. Pre-fault load flow and faults to be located were carried out by multiplying average loading of each transformer by a random number (λ), varying between 0.95 and 1.05, according to the following equation:

$$\mathbf{S}_i = \beta_i \lambda_i \mathbf{S}_i^{Nom} \qquad (11)$$

where:

$\mathbf{S}_i$: Complex power assumed for the transformer *i*;

$\mathbf{S}_i^{Nom}$: Nominal complex power for the transformer *i*;

β_i: Average loading of the transformer *i*;

λ_i: Random number.

Fault location calculations were carried out taking into account that the total power rating measured at the sending node at the substation was allocated for each feeder transformer according to (2), and fault resistance equal 10 ohms.

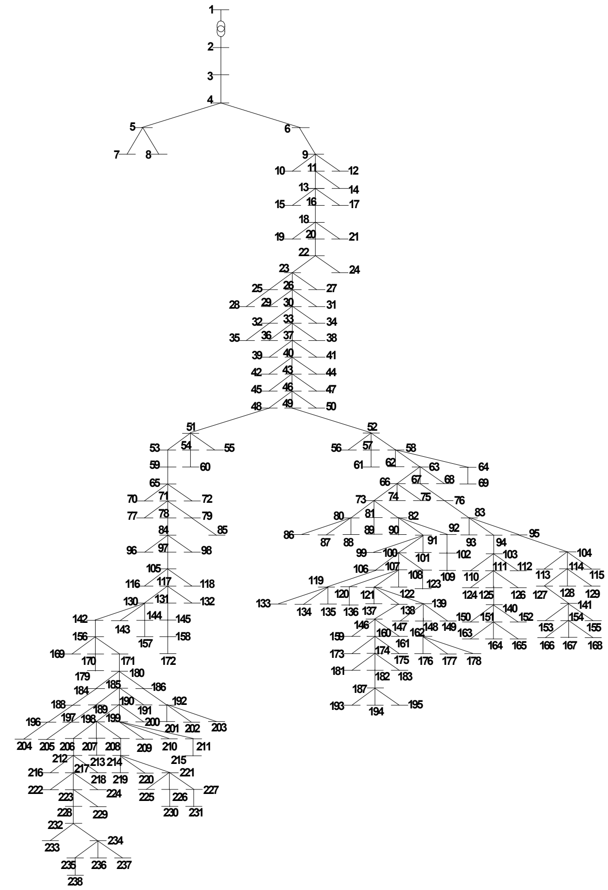

Fig. 3 Real-life feeder used for testing the proposed fault location technique.

Taking into account that five voltage measurement devices were placed at nodes 11, 109, 166, 176 and 225, fault simulations were performed for each feeder node and the proposed technique for fault location was applied to locate the faults. Two hundred thirty-six faults were simulated on the feeder (from node 3 to node 238) and the results are shown in table I.

Table I
Fault location results

Obtained results for 236 fault simulations	Total
Accurate fault location	208
Actual faulted node ranked as second faulted node	19
Actual faulted node ranked as third faulted node	6
Actual faulted node ranked as fourth faulted node	3

Table I shows that among the 236 simulated faults on the feeder, 208 of them were accurately pinpointed while 19 of them were placed in the second, six of them in the third and three of them in the fourth position of the rank. Taking into account the load deviation between fault simulation and fault location process along with the feeder size and the number of laterals present on the feeder, these twenty-eight wrong indications do not affect the reliability and robustness of the proposed technique because all the nodes ranked before the actual faulted node are within the same geographic area, *i.e.*, nodes on laterals geographically far from the faulted node were not pointed as the likely fault location.

Fig. 3 shows the values of *fb*, (10), for the likely faulted nodes ranked for a fault located accurately. Fig. 4, 5 and 6 show the values of *fb* for the likely faulted nodes ranked for three different faults, which were not located accurately.

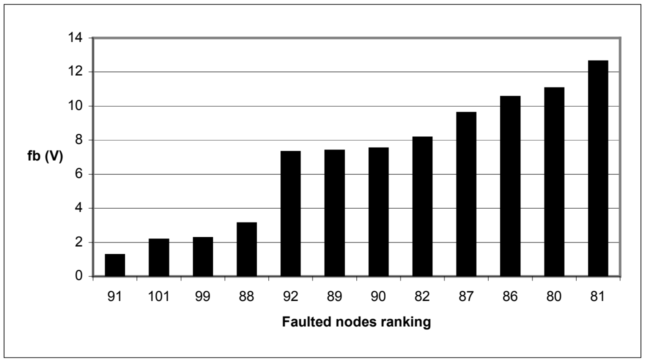

Fig. 3 Faulted nodes ranking for a fault occurring at the node 91.

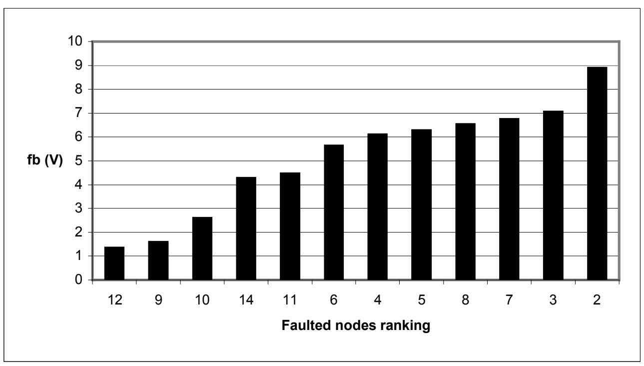

Fig. 4 Faulted nodes ranking for a fault occurring at the node 9.

Fig. 4 shows the faulted node ranking for fault occurrence at node 9. It can be noted that the node 12 is ranked as the first candidate node for fault location. Although node 12 is indicated as the likely faulted node the distance between nodes 9 and 12 is only 4 meters.

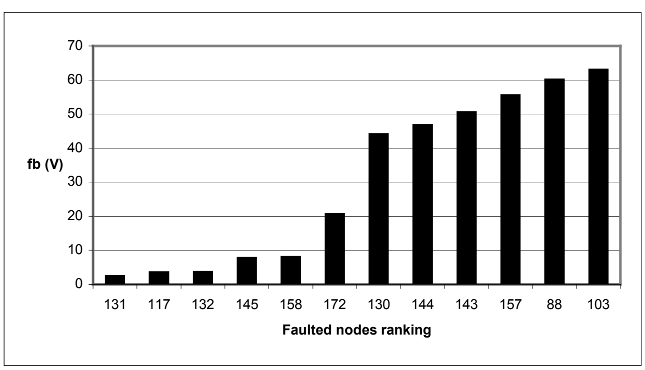

Fig. 5 Faulted nodes ranking for a fault occurring at the node 132.

Fig. 5 shows the faulted node ranking for fault occurrence at node 132. It can be noted that the node 131 is ranked as the first candidate node for the fault location, the node 117 is ranked as the second one and the node 132 is ranked as the third one. Although node 132 is indicated in the third position of the faulted node ranking, the distance between nodes 131 and 132 is 96.6 meters, and the distance between nodes 117 and 132 is 59.4 meters.

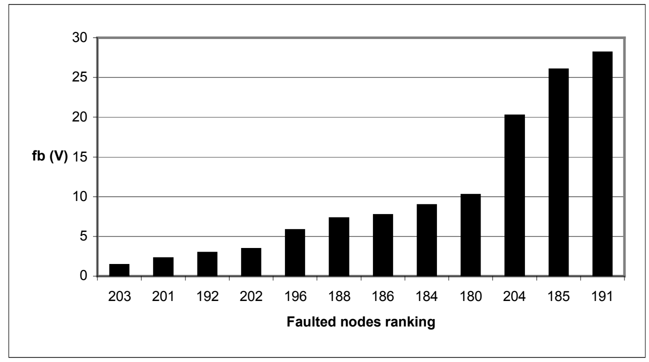

Fig. 6 Faulted nodes ranking for a fault occurring at the node 202.

Fig. 6 shows the faulted node ranking for fault occurrence at node 202. It can be noted that the node 203 is ranked as the first candidate node for fault location, the node 201 is ranked as the second one, the node 192 is ranked as the third one and the node 202 is ranked as the fourth one. In spite of node 202 being indicated in the fourth position of the faulted node ranking, the distance between nodes 202 and 203 is 95.1 meters, the distance between nodes 201 and 202 is 72.8 meters, and the distance between nodes 192 and 202 is 49.1 meters.

Analyzing the twenty-eight cases where the actual faulted nodes were not located accurately, it can be verified that the results still present good estimates. Although first, second or third position of the faulted nodes ranking are filled with non-faulted nodes, these nodes are always in close proximity of the faulted node. The usage of voltage measurements for carrying out fault location always provides as results the nodes that are in the neighborhood of the faulted node. Possible nodes located far from the faulted node are excluded from the results without the use of any auxiliary methods of diagnosis for selecting the likely faulted point. By using the results from the fault location technique, the maintenance crews are able to locate either the actual faulted node or they can have a reliable indication of the faulted area in a fast and efficient way. With this approach the time spent on performing switching for restoration and the outage time for the customers are considerably decreased.

IV. CONCLUSIONS

A technique for locating single line-to-ground faults on distribution feeders using voltage measurements along the feeder was presented in this paper. At least two measurement devices should be installed for performing fault location and the maximum number is defined by taking into account technical and economic constraints.

Results show that the technique is robust and efficient in finding the faulted node and/or the area near to the actual faulted node. The usage of voltage measurements along the feeder enables the proposed technique to locate faults excluding the nodes located far from the actual faulted node without using an auxiliary diagnosis method, like matching waveform scenarios and analyses of the pre- and post-fault power measured at the substation. These characteristics of the presented technique are very important for electric utilities for meeting standards imposed by the regulatory agencies.

As it was observed in the presented results, in some cases the actual faulted node was not pointed accurately. This has occurred due to the main error source that affects the accuracy of fault location techniques on distribution feeders. This error source is related to the transformers loading estimation. It can lead the fault location technique to indicate the likely fault location as being upstream or downstream from the actual faulted point. In some cases, it appears that the first node in the node ranking is further away from the actual faulted point than the second, third or fourth one, but the distance is so small that it does not have significant effect on the quality of the obtained results.

One important characteristic of the proposed technique is that it can be easily implemented using power quality measurement devices already installed on the feeder since they can provide data required for carrying out fault location. This way, the power quality devices play two functions, namely, power quality analysis and fault location. This multiple use of existing devices is an important aspect that electric utilities are considering while making future investments in the techniques and devices for improving power supply quality and network performance.

V. Acknowledgment

The first author gratefully acknowledges the Visiting Researcher position, as well as the facilities support provided by the Electrical and Computer Engineering Department at Texas A&M University.

VI. References

[1] R. Das, M. S. Sachdev and T. S. Sidhu, "A fault locator for radial subtransmission and distribution lines" in *Proc. 2000 IEEE Power Engineering Society Summer Meeting*, Seatle, Washington, pp.443-448.

[2] M. M. Saha, F. Provoost and E. Rosolowski, "Fault location method for MV cable network" in *Proc. 2001 IEE Seventh International Conference on Developments in Power System Protection*, Amsterdam, The Netherlands, pp. 323-326.

[3] M. M. Saha, E. Rosolowski and J. Izykowski, "A new fault location algorithm for distribution networks" in *Proc 2004 IEE Eighth International Conference on Developments in Power System Protection*, Amsterdam, The Netherlands, pp. 168-171.

[4] A. A. Girgis, and C. M. Fallon, "Fault location techniques for radial and loop transmission systems using digital fault recorded data", *IEEE Trans. Power Delivery*, vol. 7, pp. 1936-1945, Oct. 1992.

[5] A. A. Girgis, C. M. Fallon, and D. L. Lubkeman, "A fault location Technique for rural distribution feeders", *IEEE Trans. Industry Applications*, vol. 29, pp. 1170-1175, Nov. 1993.

[6] M. Lehtonen, A. Matsinen, E. Antila, J. Kuru, P. Vuorenpaa, E. Matinlassi and S. Pettissalo, "Automatic fault management in distribution networks" in *Proc. 2001 CIRED - 16th International Conference and Exhibition on Electricity Distribution*.

[7] R. K. Aggarwal, Y. Aslan, and A. T. Johns, "New concept in fault location for overhead distribution systems using superimposed components", *IEE Proc. Generation, Transmission and Distribution*, vol. 44, pp. 309-316, May 1997.

[8] J. Zhu, D. L. Lubkeman, and A. A. Girgis, "Automated fault location and diagnosis on electric power distribution feeders", *IEEE Trans. Power Delivery*, vol. 12, pp. 801-809, Apr. 1997.

[9] S. J Lee, M. S. Choi, S. H. Kang, B. G. Jin, D. S. Lee, B. S. Ahn, N. S. Yoon, H. Y. Kim, and S. B. Wee, "An intelligent and efficient fault location and diagnosis scheme for radial distribution systems", *IEEE Trans. Power Delivery*, vol. 19, pp. 524-532, Apr. 2004.

[10] E. C. Senger, G. Manassero, C. Goldemberg, and E. L. Pellini, "Automated fault location system for primary distribution networks", *IEEE Trans. Power Delivery*, vol. 20, pp. 1332-1340, Apr. 2005.

[11] P. Jarventausta, P. Verho, and P. Partanen, "Using fuzzy sets to model the uncertainty in the fault location process of distribution networks", *IEEE Trans. Power Delivery*, vol. 9, pp. 954-960, Apr. 1994.

[12] V. N. Gohokar and V. V. Gohokar, "Fault location in automated distribution network" in *Proc. 2005 IEEE International Symposium on Circuits and Systems*, pp. 3898-3901.

[13] H. Li, A. S. Mokhar and N. Jenkins, "Automatic fault location on distribution network using voltage sags measurements", in *Proc. 2005 CIRED – 18th International Conference and Exhibition on Electricity Distribution.*

[14] M. Kezunovic, S. Luo and D. R. Sevcik, "A novel method for transmission network fault location using genetic algorithms and sparse field recordings" in *Proc. 2002 IEEE Power engineering Society Summer Meeting,* Chicago, Illinois, pp. 1101-1106.

[15] R. A. F. Pereira, L. G. W. da Silva and J. R. S. Mantovani, "Localizacao de faltas fase-terra em alimentadores radiais de distribuicao utilizando aquisicao de dados esparsos sincronizados", in *Proc. 2004 XV Congresso Brasileiro de Automatica,* Gramado, Brazil.

[16] R. A. F. Pereira, L. G. W. da Silva, M. Kezunovic and J. R. S. Mantovani, "Optimized placement of voltage measurement devices for determining location of single line-to-ground faults on overhead electric power distribution feeders", *submitted to the 2006 XVI Congresso Brasileiro de Automatica*, Salvador, Brazil.

VII. Biographies

Rodrigo Aparecido Fernandes Pereira (S'06) received his B.Sc. and the M.S. degrees from UNESP/Ilha Solteira-SP (Brazil), in 2001 and 2003, respectively. He is working towards a Ph.D. degree in Electrical Engineering at UNESP/Ilha Solteira-SP (Brazil). Currently, he is with the Electrical and Computer Engineering Department at Texas A&M as a Visiting Researcher. His general research interest is in the electric power systems reliability and control areas, mainly expert systems for fault location on distribution feeders.

Luis Gustavo Wesz da Silva received the B.Sc. degree in 1999 from UNIDERP-MS and the M.S. and Ph.D degrees in Electrical Engineering from UNESP/Ilha Solteira-SP (Brazil), in 2002 and 2005, respectively. His general research interest is in the areas of reliability and control of electrical power systems.

Mladen Kezunovic (S'77-M'80-SM'85-F'99) received the Dipl. Ing. Degree in electrical engineering from the University of Sarajevo, Bosnia-Herzegovina, in 1974, and the M.S. and Ph.D. degrees from the University of Kansas, Lawrence, in 1977 and 1980, respectively.

Currently, he is the Eugene E. Webb Professor and Director of Electric Power and Power Electronics Institute at Texas A&M University. His main interests are digital simulators and simulation methods for relay testing as well as application of intelligent methods to power system monitoring, control, and protection. Dr. Kezunovic is also a Fellow of IEEE and a member of the CIGRE-Paris.

José Roberto Sanches Mantovani (M'06) received the B.Sc. degree in 1981 from UNESP/Ilha Solteira-SP, and his Ph.D degree in Electrical Engineering from UNICAMP/Campinas-SP, in 1995. Currently he is an Associate Professor in the Electrical Engineering Department of UNESP/Ilha Solteira-SP. His general research interests are in the area of planning and control of electrical power systems.