Modified Z-bus Loss Allocation Method for Distribution Network with Distributed Generation

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Motivation for loss allocation and its difficulties

In competitive environment in distribution systems, responsibilities of the players in the network should be cleared. With respect to this rule:

The purpose of loss allocation is to assign the distribution losses to each individual distributed generation and load.

Loss allocation is a difficult task, because losses in the distribution system branches are nonlinear functions of generations and loads and their locations in the feeders.
Why Loss Allocation is Important?

- Increasing Penetration of DG in Distribution Network
- Restructuring

Loss Allocation

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A loss allocation technique should be:

- easy to understand and based on real data of the network;
- carefully designed to avoid discrimination between users;
- able to recover the total amount of the losses;
- consistent with the rules of competitive electricity markets;
- economically efficient and able to send out economic signals aimed at increasing the efficiency of the network;
- able to provide correct signals concerning the size and location of loads and DG sources in the network;
- applicable to different situations, following the generation and load patterns especially in stochastic generation.
Some remarks for loss allocation

• In restructured power systems all of system operation costs must be allocated between consumers and generators through exact instruction to avoid unfairness.
• Both of generators and consumers should pay network loss cost because of jointly using system structure.
• Because of nonlinear relation between system loss and generation and loads, exact allocating system loss between generators and loads is difficult.
• Most of reported methods for loss allocation is for transmission network.
• The loss allocation method should be:
Some types of loss allocation methods for transmission systems

Different types of loss allocation procedures are:

- pro-rata
- marginal
- proportional sharing
- circuit-based
- transaction-based
Proposed approach-outline

• Using Z bus (Circuit based) loss allocation method
• Assignment of the loss also to slack bus with consideration of the network configuration and load distribution in the network
• Using Neural Network for loss allocation
Proposed Method

- Load flow with Matpower
- Allocating loss with Z-bus method
- Sharing slack bus loss among other buses
- Calculating total allocated loss to each bus
Z-Bus Loss Allocation Method

\[ P_{\text{loss}} = \sum_{k=1}^{n} L_k \]

\[ P_{\text{loss}} = \text{Real} \left\{ \sum_{k=1}^{n} V_k I_k^* \right\} \]

\[ P_{\text{loss}} = \text{Real} \left\{ \sum_{k=1}^{n} I_k^* \left( \sum_{j=1}^{n} Z_{kj} I_j \right) \right\} \]

\[ P_{\text{loss}} = \text{Real} \left\{ \sum_{k=1}^{n} I_k^* \left( \sum_{j=1}^{n} R_{kj} I_j \right) \right\} + \text{Real} \left\{ \sum_{k=1}^{n} I_k^* \left( \sum_{j=1}^{n} j X_{kj} I_j \right) \right\} \]

\[ P_{\text{loss}} = \text{Real} \left\{ \sum_{k=1}^{n} I_k^* \left( \sum_{j=1}^{n} R_{kj} I_j \right) \right\} \]

\[ L_k = \text{Real} \left\{ I_k^* \left( \sum_{j=1}^{n} R_{kj} I_j \right) \right\} \]

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Some remarks

• If there is single phase DG, it is necessary to use three phase Z bus matrix

• However load modeling can not be considered.
Difficulty of using Z-Bus method for distribution network

- Z-Bus method allocates significant part of system losses to the slack node (substation) with increasing number of network busses which raises in distribution networks
- slack node has no responsibility for distribution network losses
- allocated loss to the slack node should be shared among other network users (consumers and DGs) in a fair way
Loss assignment of slack bus

\[ L_{k\text{-}\text{shared}} = \frac{I_k l_k}{\sum I_i l_i} L_{0(z\text{-bus})} \]

- \( L_{k\text{-}\text{shared}} \): Allocated loss of slack node to \( k^{th} \) bus
- \( I_k \): \( k^{th} \) bus current magnitude obtained from power flow
- \( l_k \): Direct length of \( k^{th} \) bus on distribution feeder from slack node (substation)
- \( L_{0(z\text{-bus})} \): Allocated loss to slack node (substation) with z-bus method
- \( n \): Number of network busses

\[ L_k = L_{k(z\text{-bus})} + L_{k\text{-}\text{shared}} \]

- \( L_k \): Allocated loss to \( k^{th} \) bus with proposed method
- \( L_{k(z\text{-bus})} \): Allocated loss to \( k^{th} \) bus with z-bus method
CASE STUDY
Allocated Loss to DG’s

- allocated loss to selected busses differs among daily hours
- Some DGs for example, DG-1 has negative loss .it gets incentive in this hours for DG1 for generation
- if allocated loss to a user of distribution network is positive in certain hours it should pay loss cost in those hours

Loss DG in Bus-33 in 24 hour

Loss DG in Bus-40 in 24 hour
Allocated Loss to Load’s

- In restructured power systems, distribution network users can use this information to shift their power production (or power consumption) to hours that their allocated loss is minimum in those hours.
- This means that the proposed technique in this paper can be used in demand side management programs.
SENSITIVITY ANALYSIS

- resistance of line 32-33 is increased and then modified z-bus loss allocation technique is applied to new structure of distribution test system.
- Since only connected user to this line is DG4, thus increased system loss because of increasing resistance in line 32-33 should be allocated only to this DG and allocated loss to other system busses should be constant. This fact is obviously shown in figure.
sensitivity of allocated loss to network busses with increasing line 18-19 resistance

- As it is shown only allocated loss to DG1 is increased and allocated loss to other system busses is constant
Neural Network for loss allocation

Generating training pattern for loss allocation for different load and generation levels

- Training a neural network using training pattern
- Using the trained neural network for loss allocation
Neural network training and using

- Load in buses
- Generating levels in DGs
- Line Impedances
- Configuration of the network

Neural Network

Assignment of losses to buses
Neural Network application for loss allocation- Training curve for one hidden layer with 20 neurons
Neural Network vs modified Z- Bus method for one hidden layer with 20 neurons
• The weak point of the neural network for loss allocation is dependency to the configuration of the network

• The neural network for loss allocation can be used for real time application (The strong point)

• The best configuration of neural network for loss allocation should be determined using try and error and this is case based (The weak point)
CONCLUSION

• The allocation of the system losses to suppliers and consumers is a challenging issue for the restructured electricity business.
• This paper presents a loss allocation technique for allocating distribution network loss to consumers and DGs. It is can used in retail market environment.
• With this proposed method distribution network loss had been allocated between DG’s and loads considering their location and size.
• Neural network can be used for loss allocation in real-time applications.
• If the location of DGs vary in the network, it is need to retraining the neural network! therefore it is not robust to reconfiguration in distribution network!
• This method can be used for single phase DGs also.
THANKS FOR YOUR ATTENTION