Optimal placement of DSTATCOM in Electrical Distribution System

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Abstract

Currently the electrical energy demand is rising faster way in developing countries like India. As a result, more distribution losses and low voltage profiles in the large and complex electrical distribution systems (EDS). Studies observed that nearly 10-15% of the total generated electrical power is fed on as I2R losses at the stage of distribution level. The consumers voltages have reduced when moved away from the substation and such consumers contribution in distribution losses is more based on associated connected load of consumers. In addition to that voltage stability decreases and maximum loadability margin also reduced in the distribution lines. Subsequently, it will be imperative to improve the capacity of power transmission in EDS. The planning and optimization of compensating device and Distributed Generation (DG) are estimated to improve the reduction of energy losses and beautify the consumer voltage profile in the EDS. The recommended approaches introduce with planning and optimization using simple and fast load flow solution for optimal placements and optimal sizes of the Distribution Static Synchronous Compensator (DSTATCOM) with different optimization methods.

Keywords: *EDS, D-STATCOM, ITLBO.*

1. Introduction

Generally, the radial distribution networks have high R/X ratio, which causes high line losses in the system and it leads to affect the system stability. So many researchers approximated that the distribution system power loss is high compared to transmission system. From the consumer point of view, the power loss reduction is one of the important issues to improve the overall efficiency of the power delivery [1]. Reactive power compensation is one of the best ways to reduce the losses in the distribution system. The shunt capacitors and serious voltage regulators are traditionally used for reactive power compensation in the distribution system. But these devices cannot able to provide the reactive power continuously and they have very slow response. In addition to that the shunt capacitors produce oscillation in the distribution system when it combines with inductive circuits [2].

Now a days the application of FACTS concept such as DSTATCOM has been applied for distribution system for line loss reduction, voltage profile enhancement, power quality improvement and load balancing etc., Compare with other reactive power compensation devices, DSTATCOM has many features, such as low power losses, less harmonic production, high regulatory capability, low cost and compact size. The primary function of DSTATCOM is to supply reactive power in the distribution system in order to reduce the line losses, power factor correction and voltage profile enhancement.

DSTATCOM is predicted to play significant role in the radial distribution systems due to the increasing power system load.

Optimum allocation of DSTATCOM maximizes the load ability, power loss minimization, stability enhancement, reactive power compensation and power quality enhancement [8]. To determine the optimal location and sizing of DSTATCOM has a considerable impact in radial distribution system. In appropriate placement in some situations can reduce the benefits and even endanger the entire system operation. Only a few research works were done in the area of DSTATCOM allocation [3].

No work done in the literature to focus on the power loss reduction along with system voltage stability improvement reduces the voltage deviation, improve the LLM and decrease the loss allocation to consumer [4]. This work proposed various indices based on the power losses, voltage deviation, voltage stability, LLM and consumer loss allocation. Proposed a generalized multi objective function which can use in any of the planning optimization to improve the EDS performance [5].

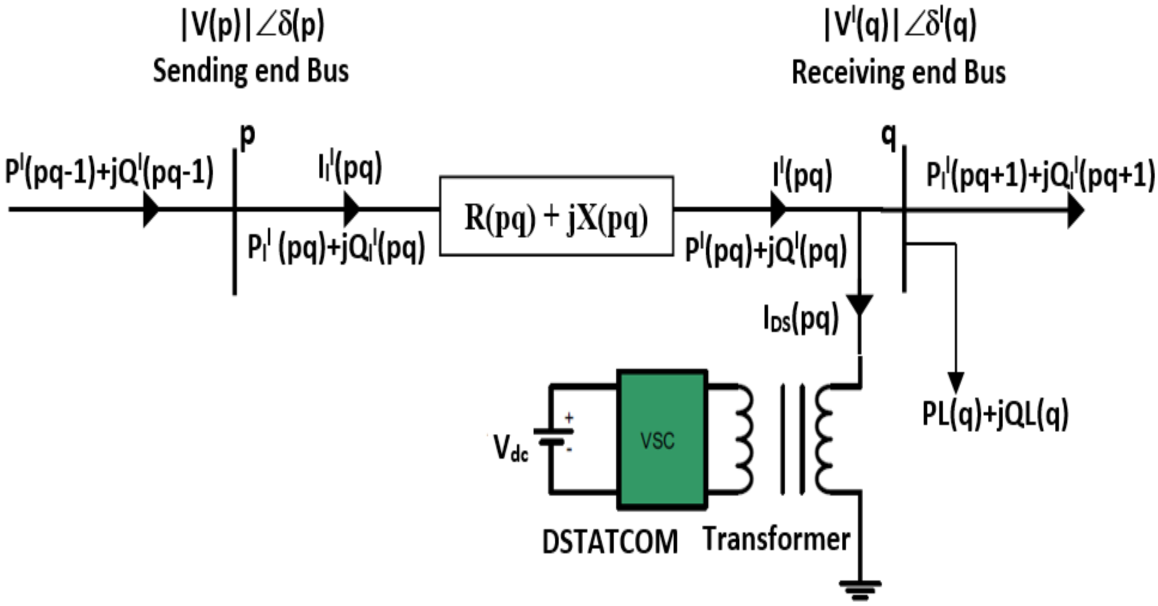

Figure.1: Equivalent circuit model of EDS of a typical branch pq with DSTATCOM

A new approach is investigated to find the optimal location and sizing of DSTATCOM with an objective function of minimizing the total system power losses by including the voltage stability, voltage deviation, LLM and loss allocation to consumer. Improved Teaching Learning Based Optimization algorithm is used to find the optimal location and sizing of single and multiple DSTATCOM. The proposed work is tested on 33-node and 69-node EDS. The obtained result shows that optimal placement and sizing of DSTATCOM in the EDS effectively reduces the total power losses of the system and also improve the performance of the EDS.

2. Various Impact Indices for the Multi-objective Problem

For the planning and optimization of EDS, the multi-objective formation includes six individual objectives that are transformed to related impact indices in or to make the analyze all objective simultaneously with simple analysis. Following are the indices proposed to handle the planning and optimization EDS problem effectively.

2.1 Index for Power losses based on available load (IAPL and IRPL)

The system operates at maximum performance represent as reduces the losses. In this case, the real and reactive power loss indices are defined as follows respectively [6].

$$IAPL = \left(\sum_{pq=1}^{br} P_{loss}(pq) / \sum_{q=1}^{nd} PL(q)\right) \quad (1)$$

$$IRPL = \left(\sum_{pq=1}^{br} Q_{loss}(pq) / \sum_{q=1}^{nd} QL(q)\right) \quad (2)$$

where

$\sum_{pq=1}^{br} P_{loss}(pq)$ is total APL in kW

$\sum_{pq=1}^{br} Q_{loss}(pq)$ is total RPL in KVAr

$\sum_{q=1}^{nd} PL(q)$ is total active load in kW

$\sum_{q=1}^{nd} QL(q)$ is total reactive load in kVAr

Planning and optimization of EDS will decrease the total network losses, which means near zero values of IAPL and IRPL.

2.2 Index for Deviation of bus voltages (IVDI)

The system voltage deviation index (VDI) is defined with respect to eqn. above equations for EDS. The index for the voltage deviation is the system voltage deviation index only as shown below

$$IVDI = VDI \quad (3)$$

The decreasing value of IVDI refers to the improvement of voltage profile as well as voltage regulation at the nodes. Any planning and optimization of EDS will decrease the system voltage deviation index and make it zero value of IVDI.

2.3 Index for consumer loss allocation based on total APL (ICPL)

The loss allocation to consumer far away from the substation is high with the proposed PLAM . It is needed to observe the consumers with high loss allocation burden and any allocation method should always give the best to reduce their loss allocation. The index is developed to observe the maximum loss allocation consumer based on the total system APL.

$$ICPL = \max_{q=1\ to\ nd}\left(CP_{loss}(q) / \sum_{pq=1}^{br} P_{loss}(pq)\right) \quad (4)$$

Where

$CP_{loss}(q)$ is the loss allocation of q^{th} consumer

For any planning and optimization, it is accepted to reduce the burden of high loss allocation to the customer and ICPL should reach near to zero and loss allocation to most of the consumers will decrease.

2.4 Index for VSI (IVSI)

The VSI gives a significant detail about the voltage stability of the radial distribution systems. In this approach, VSI is taken as the decisive factor which variation of VSI value indicating the system voltage stability during of any planning and optimization in EDS. The index of VSI is defined as

$$IVSI = \min_{q=1\ to\ nd}\left(VSI(q)\right) \qquad (5)$$

The intensity of stability can measure the distribution system using the IVSI and thereby necessary action, possibly taken if the index indicates the instability condition of the system. The system operates at secure and stable condition the evaluated VSI values are greater than zero, otherwise instability occurs.

2.5 Index for LLM (ILLM)

With planning and optimization of EDS significantly changes the power flow in various sections of the EDS. The maximum loading allowed with the addition of branch LLM is the acceptable limit of branch to avoid the system instability. The ILLM index gives in details of minimum loading of LLM from all branches of LLMs in EDS.

$$ILLM = \min_{pq=1\ to\ br}\left(\frac{LLM(pq)}{LML(pq)}\right) \qquad (6)$$

It is needed to increase the ILLM value increase to operate the EDS system with high LLM values and utilize the existing lines for handling the future load growths.

3. Flow Chart for DSTATCOM Placement and Sizing using ITLBO Algorithm

To solve the optimal location and size of the single and multiple DSTATCOM problem in EDS, ITLBO is applied to minimize the MOPI function eqn. (7) [7]. Initially, ITLBO algorithm parameters (such as number of generations, population size (i.e. number of learners), number of teachers and number of subjects), the number of DSTATCOMs locations and according to that sizes, constraints and the system specifications, including the bus and line data, should be considered as inputs of the ITLBO. The ITLBO algorithm based MOPI is given by

$$MOPI = w_1.IAPL + w_2.IRPL + w_3.IVDI + w_4.ICPL + w_5.\left(\frac{1}{IVSI}\right) + w_6.\left(\frac{1}{ILLM}\right) \qquad (7)$$

The location of DSTATCOMs can be chosen as any integer number between 2 and the maximum number of system nodes (as 1 is the substation) and size of corresponding location DSTATCOM changes from 5 kVAr to less than or equal to total reactive load of EDS. The variables for optimization are the location of the DSTATCOMs and sizes of imaginary DSTATCOMs powers.

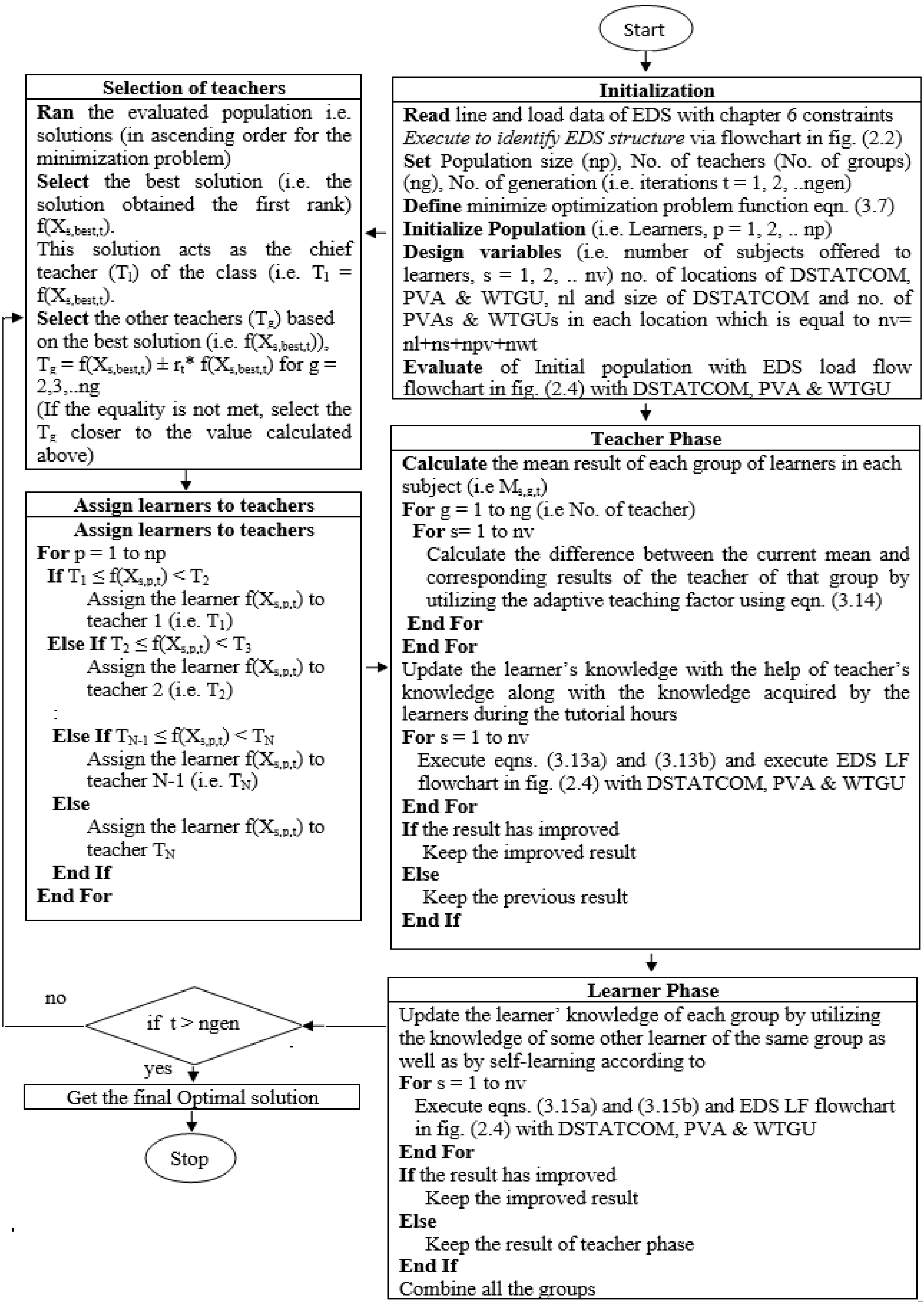

Figure.2: Flow chart for DSTATCOM, PVA and WTGU Placement and Sizing using ITLBO

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4. Conclusion:

In this work, the utilization of the ITLBO procedure for solving the DSTATCOM location sizing problem for minimizing the system MOPI function with different number of DSTATSOMs has been considered. In this proposed method a generalized MOPI function developed and which is used to search the optimal location and size of DSTATCOM. DSTATCOM location and sizes can be found by using ITLBO among a large number of combinations by optimizing the objective function. The present approach reduces the power loss and improves the bus voltage accurately and effectively in the EDS to enhance the minimum LLM and reducing the consumer loss allocation.

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