Optimal Placement and Sizing of DG in Distribution Network from Minimum Total Real Power Loss of the System Viewpoint

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Abstract:--*This paper presents a novel approach such as Genetic Algorithms (GA) for optimal placement of distributed generation (DG) in distribution network with different load models (DLMs) such as constant (CLM), industrial (ILM), residential (RLM), commercial (COLM) and reference (RELM) load models from minimum total real power loss view point. The proposed methodology has been illustrated for IEEE-37 bus test system. This work is very much useful for reseachers and scientific persons regarding the DG planning in distribution network with different load models (DLMs) from minimization of total real power loss of the system. This work also helpful for whose persons are working in the field of renewable energy sources.*

Keywords: Distributed generation (DG), Distribution network, Different load models (DLMs), Genetic Algorithm (GA), Power flow analysis.

Abbreviations

AC	Alternating current	P_{DG}	Real power of DG
AI	Artificial intelligence	PF_WDG	Power factor With DG
AIS	Artificial immune system	PF_WODG	Power factor without DG
CIGRE	International council large electric systems	PF_{DG}	Power factor of DG
CIT	Computational intelligence techniques	PSI	Power stability index
CLM	Constant load model	PSO	Particle swarm optimization
COLM	Commercial load model	PURPA	Public utilities regulatory policy act
DC	Direct current	PV	Photovoltaic
DE	Differential evolution	Q_{DG}	Reactive power of DG
DER	Distributed energy resources	RELM	Reference load model
DG	Distributed generation	REPL_WDG	Reactive power loss with DG
DGP	Distributed generation planning	REPL_WODG	Reactive power loss without DG
DLM's	Different load models	RLM	Residential load model

DOE	Department of energy	RPELI	Reactive power index
DPSN	Distribution power system network	RPL_WDG	Real power loss With DG
EG	Embedded generation	RPL_WODG	Real power loss Without DG
EWG	Embedded wind generation	RPLI	Real power index
GA	Genetic algorithm	SPF	System power factor
ICA	Imperialist competitive algorithm	T&D	Transmission and distribution
ILM	Industrial load model	V_{max}	Maximum voltage limit
LOC_{DG}	Location of DG	V_{min}	Minimum voltage limit
MVA_{DG}	Mega volt ampere capacity of DG	WDG	With DG
MW	Mega watt	WODG	Without DG
Symbols			
Alpha	Exponent value for real power voltage dependent load model	*L*	Line number
$Alpha_c$	Exponent value for real power voltage dependent commercial load model	P_{int}	Real power intake
$Alpha_i$	Exponent value for real power voltage dependent industrial load model	Q_{int}	Reactive power intake
$Alpha_r$	Exponent value for real power voltage dependent residential load model	S_{int}	MVA intake
Beta	Exponent value for reactive power voltage dependent load model	S_L	Line apparent power limit
$Beta_c$	Exponent value for reactive power voltage dependent commercial load model	W_c	Relevant factor for commercial load
$Beta_i$	Exponent value for reactive power voltage dependent industrial load model	W_i	Relevant factor for industrial load
$Beta_r$	Exponent value for reactive power voltage dependent residential load model	W_r	Relevant factor for residential load

1. Introduction

Distributed Generation (DG) is a small generator spotted throughout a power system network, providing the electricity locally to load customers [1]. DG can be an alternative for industrial, commercial and residential applications. DG makes use of the latest modern technology which is efficient, reliable, and simple enough so that it can compete with conventional large generators in some areas [1].

In recent years, the power industry has experienced significant changes on the distribution power system primarily due to the implementation of smart-grid technology and the incremental implementation of distributed generation. DG is simply defined as the decentralization of power plants by placing smaller generating units closer to the point of consumption, conventionally ten mega-watts or smaller [2]. While DG is not a new concept, DG is gaining widespread interest primarily for the following reasons: increase in customer demand, advancements in technology, economics, deregulation, environmental and national security concerns.

The distribution system is conventionally radial and operates without installed generation units. The electrical energy is supplied to the distribution network through transmission at the Grid Supply Point. Therefore, power flows in one direction from transmission to distribution [3]. At present, there is increasing number of the generation connected to the distribution system which is generally called Distributed Generation. The location and amount of power supplied from the DG into the distribution system have influence on the operation of the system. They can either increase or decrease the efficiency and stability of the system. Large power supplied from the DG can even reverse the direction of power flow. Therefore, the suitable location and sizing of the DG is preferred. In [1], the optimal location of a specific sizing DG is determined using genetic algorithm technique. The objective is to reduce losses of the system. This thesis determines the optimal location and the sizing of the DG in order to minimize total losses of the distribution network.

1.1 Literature review

Deependra Singh *et al.* [1], presented a novel technique for placement of DG in electric power systems. A GA based approach for sizing and placement of DG keeping in view of system power loss minimization in different loading conditions is explained. Minimal system power loss is obtained under voltage and line loading constraints. A. N. Venkateswarlu *et al.* [2], addressed the impact of Static Var Compensators (SVC) and DG on available transfer capability. Using repeated power flow, the voltage stability constrained available transfer capability has been improved. Hasan Hedayati *et al.* [3], suggested a method for placement of DG units in distribution networks. This method is based on the analysis of power flow continuation and determination of most sensitive buses to voltage collapse. This method is executed on a typical 34-bus test system and yields efficiency in improvement of voltage profile and reduction of power losses; it also may permit an increase in power transfer capacity, maximum loading, and voltage stability margin. Devender Singh *et al.* [4], discussed the effect of load models on DG planning in distribution system is investigated in this work. It is shown that load models can significantly affect the DG planning. Normally a constant power (real and reactive) load model is assumed in most of the studies. Such assumptions may lead to inconsistent and misleading results about deferral values, loss reduction, payback period, and other subsequent calculations. Duong Quoc Hung *et al.* [5], addressed the analytical expressions for finding optimal size and power factor of four types of DG units. DG units are sized to achieve the highest loss reduction in distribution networks. M.R.Haghifam *et al.* [6], presented a strategy is presented for the placement of DG units in the distribution networks in an uncertain environment. Uncertainties in the system are modeled using fuzzy numbers. R.A.Jabr *et al.* [7], presented an ordinal optimization (OO) method for specifying the locations and capacities of distributed DG such that a trade-off between loss minimization and DG capacity maximization is achieved. Rajendra Prasad Payasi *et al.* [8], presented the DG technologies, which include both conventional and non-conventional type of energy sources for generating power, are gaining momentum and play major role in distribution system as an alternative distribution system planning option. The penetration of DGs is potentially beneficial if distributed generation planning (DGP) is optimal i.e. their site and size are selected optimally by optimization of single or multi-objective function under certain operating constraints. H.Yassami *et al.* [9], presented three different objective functions are considered in this study: (1) minimization of power generation cost (2) minimization of active power loss (3) maximization of reliability level. The goal is to optimize each objective function. The site and size of DG units are assumed as design variables. Sami Repo *et al.* [10], presented considers the voltage issues and the load transfer capability of distribution network including windmills. The proposed method is based on ring operation of the distribution network and control of windmill active and reactive power. The applicability of the proposed method is tested with load-flow simulations on a real life distribution network and planned windmills. Gopiya Naik *et al.* [11], presented a simple method for real power loss reduction, voltage profile improvement, substation capacity release and is based on voltage sensitivity index analysis. Power flow analysis is done using the forward-backward sweep method. Study carried out on an IEEE-33 bus test system validates the suitability of this proposed method. Barry Hayes *et al.* [12], presented the application of a closed-loop state estimator for improving situational awareness in distribution systems. A predictive database is created and applied to forecast future network states, in order for short-term (e.g. day-ahead) planning to be carried out. Sami Repo *et al.* [13], presented the improvements on the short-term network planning of a distribution system and DG on the open electricity market. The interconnection of DG is currently based on worst case principle thus great savings in network investments can be achieved by applying a statistical planning approach. B. Singh *et al.* [14], presented a state-of-the-art on enhancement of different performance parameters of power systems by optimally placed DG & FACTS controllers in power Systems. Also this paper presents the current status on enhancement of different performance parameters of power systems by optimally placed DG & FACTS controllers in power Systems.

S.Kumar Injeti *et al.* [15], presented the planning and operation of active distribution networks, with respect to placement and sizing of DG are discussed with the help of a new methodology. DG unit placement and sizing were calculated using fuzzy logic and new analytical method respectively. Manoj Kumar Nigam *et al.* [16], presented the impacts that were raised due to the connection of distributed generation into the existing network. To test the effectiveness of proposed method an IEEE 30 bus network is used. The impacts are studied and are shown with the help of graph. F.Fatahian *et al.* [17], presented two methods to determine the size and location of DG units are presented in distributed system. Four objective functions include, cost, power loss, voltage profile and environmental attributes are intended. The proposed algorithms are tasted on the 34- bus radial system. The results show that voltage profile and power loss improve with proposed solution. Satish Kumar Injeti *et al.* [18], presented a novel methodology for finding the optimal size and location for installation of DG so as to minimize total power loss in radial distribution system. DG unit placement and sizing were calculated using fuzzy logic and new analytical method respectively. Mingxin Zaho *et al.* [19], presented the superposition method of time-varying characteristics is proposed to deal with diversity problem of maximum loads. In the basis of historical yearly 8760 hour varying data, we can get yearly time-varying curves for different types of load, which can be superposed into total load time-varying curve for the forecast area. S.Najafi Ravadanegh [20], presented the optimal HV substation placement problem is solved using Imperialist Competitive Algorithm (ICA) as a new developed heuristic optimization algorithm. This proposed procedure is determined the optimal location, capacity and installation time of HV substation, regarding the operating and optimization constraints. Duong Quoc Hung *et al.* [21], presented to investigate the problem of multiple DG units placement to achieve a high loss reduction in large-scale primary distribution networks. An improved analytical (IA) method is proposed in this paper. This method is based on IA expressions to calculate the optimal size of four different DG types and a methodology to identify the best location for DG allocation. Dan Zhu *et al.* [22], presented DGs sometimes provide the lowest cost solution to handling low-voltage or overload problems. In conjunction with handling such problems, a DG can be placed for optimum efficiency or optimum reliability. Such optimum placements of DGs are investigated. The concept of segments, which has been applied in previous reliability studies, is used in the DG placement. N.Khalesi *et al.* [23], presented the multi-objective function to determine the optimal locations to place DGs in distribution system to minimize power loss of the system and enhance reliability improvement and voltage profile. Time varying load is applied in this optimization to reach pragmatic results meanwhile all of the study and their requirement are based on cost/benefit forms. Gareth P Harrison *et al.* [24], presented a hybrid method employing genetic algorithms and optimal power flow aims to overcome this shortcoming. It could be applied by distribution network operators to search a network for the best sites and capacities available to strategically connect a defined number of DGs among a large number of potential combinations.Gareth P Harrison *et al.* [25], presented the multi objective optimal power flow is used to simulate how the parties' incentives affect their choice of DG capacity within the limits of the existing network. Using current U.K. incentives as a basis, this paper explores the costs, benefits and tradeoffs associated with DG in terms of connection, losses and, in a simple fashion, network deferral. R S Al Abri *et al.* [26], presented a method of locating and sizing DG units so as to improve the voltage stability margin. The load and renewable DG generation probabilistic nature are considered in this study. The proposed method starts by selecting candidate buses into which to install the DG units on the system, prioritizing buses which are sensitive to voltage profile and thus improve the voltage stability margin. C J Dent *et al.* [27], presented the capacity of DG connected in distribution networks is increasing, largely as part of the drive to connect renewable energy sources. The voltage step change that occurs on the sudden disconnection of a distributed generator is one of the areas of concern for distribution network operators in determining whether DG can be connected, although there are differences in utility practice in applying limits. M H Moradi *et al.* [28], presented a novel combined genetic algorithm (GA)/particle swarm optimization (PSO) is presented for optimal location and sizing of DG on distribution systems. The objective is to minimize network power losses, better voltage regulation and improve the voltage stability within the frame-work of system operation and security constraints in radial distribution systems. Alireza Soroudi *et al.* [29], presented a long-term dynamic multi-objective planning model for distribution network expansion along with distributed energy options. The proposed model optimizes two objectives, namely costs and emissions and determines the optimal schemes of sizing, placement and specially the dynamics (i.e., timing) of investments on distributed generation units and network reinforcements over the planning period.

1.1. Contribution of Paper

In this paper, the main objective is to find out optimal sizing & placement of DG with DLMs such as constant, industrial, residential, commercial and reference load modals for improvement of power system performances from minimum total real power loss of the system point of view by using artificial intelligence techniques such as Genetic Algorithm in distribution network. The comparisons of results are also presnted in this paper.

1.2. Organization of Paper

The organisation of paper are as follws: *Section 2* discusses the mathematical model of DG. *Section 3* introduces the GA implementation. *Section 4* discusses the simulation resultsand discussions. *Section 5* introduces the conclusion of this paper and future scope of work.

2. Mathematical Problem Formulation

The objective function of the optimal DG placement may be of single or multi-objective type. The single-objective function include in this work is to reduction of the total real power loss of the system. The most common constraints are considered in this analysis such as power flow equality constraints, bus voltage or voltage drop limits and transmission line overloading capacity for the optimal DG placement formulation in distribution systems.

2.1. Types of static load models

In traditional power flow analysis, different static load models such as the real and the reactive power load models are assumed as constant power load but in real life problem the loads can be voltage dependent *i.e.* CLM, ILM, RLM, COLM and RELM load models [25-32].The real and reactive power static load models are represented in equs. (1) - (2).

$$P_{p\_bus} = P_{0p\_bus}\left(\frac{|V_{p\_bus}|}{|V_{0p\_bus}|}\right)^{\alpha_{RLPL}} \tag{1}$$

$$Q_{p\_bus} = Q_{0p\_bus}\left(\frac{|V_{p\_bus}|}{|V_{0p\_bus}|}\right)^{\beta_{REPL}} \tag{2}$$

Where α_{RLPL} and β_{REPL} are the real and the reactive power exponents P_{p_bus} in (1)-(2), P_{p_bus}, Q_{p_bus}, P_{0p_bus}, Q_{0p_bus}, V_{p_bus} and V_{0p_bus} all are in per units. The exponent values for DLMs are given in Table 1. Thus, the value of $P_{\text{int}ake\_sys}$ and $Q_{\text{int}ake\_sys}$ are decided, mainly, by the real and reactive power load exponents *i.e.* α and β .

Table 1: Exponential values of DLMs [25-32]

DLMs	α	β
CLM	0	0
ILM	0.18	6.0
RLM	0.92	4.04
COLM	1.51	3.40
RELM	0.91	1.0

2.2 Different types of DGs

The different types of DGs (such as DG-T1, DG-T2, DG-T3 and DG-T4) are available in market. The details of such different type of DGs are explained are in Table 2.

Table 2: Different types of DGs and its examples

OPF_{DG}	DG Models	Power injection capability	Example
Unity	DG-T1	Active power only	Photovoltaic, micro turbines and fuel cells *etc.*
$0.80<OPF_{DG}<0.99$, leading	DG-T2	Active and reactive power both	Diesel engines as diesel generators and synchronous machines, co-generation *etc.*
Zero	DG-T3	Reactive Power only	FACTS controllers, bank of inductors and bank of capacitors
$0.80<OPF_{DG}<0.99$, lagging	DG-T4	Active power and consumes reactive power	doubly fed induction generators

In this paper, DG-T2 type is used for analysis point of view for investigation of IEEE-37 bus test system.

2.3 Mathematical modeling of DG

The reduction total real power loss of system by optimally placed DG in distribution systems is the main objective function [20-38]. The power loss (P_L) of the system is given in equ. (3).

$$P_L = \sum_{p,q \in N_{line}} \frac{P_{pq\_bus}{}^2 + Q_{pq\_bus}{}^2}{\left|V_{p\_bus}\right|^2} R_{pq\_bus} \tag{3}$$

The P_L is a function of all system bus voltage (V_{p_bus}), line resistances (R_{pq_bus}), P_{pq_bus} and Q_{pq_bus}. The total loss, mainly, depends on the voltage profile. Apparent power intake at main substation [20-25] is expressed in equ. (4).

$$S_{\text{int}ake\_sys} = \left[\left(P_{\text{int}ake\_sys}{}^2\right) + \left(Q_{\text{int}ake\_sys}{}^2\right)\right]^{1/2} \tag{4}$$

Where $P_{\text{int}ake\_sys}$ is the real power intake at main substation without DG, $Q_{\text{int}ake\_sys}$ is the reactive power intake at main substation without DG. The reactive power supplied by the STATCOM to the system is expressed by equ.(5).

$$Q_{STAT} = -\frac{V_{\text{int}ake\_sys}{}^2}{X_{TL}} + \frac{E_{bus}V_{\text{int}ake\_sys}}{X_{TL}}\cos\beta \tag{5}$$

The real power support by STATCOM is negative that means STATCOM absorbed the real power from system bus. Hence the real power support by STATCOM to the system is zero. Apparent power requirement for distribution system with DG and STATCOM is expressed by equ. (6).

$$S_{sys} = \left[\left(P_{intake\_sys} + P_{DG} + P_{STAT} \right)^2 + \left(Q_{intake\_sys} \pm Q_{DG} \pm Q_{STAT} \right)^2 \right]^{1/2} \tag{6}$$

Where P_{DG} , P_{STAT} and Q_{DG} , Q_{STAT} are the real and reactive power supplied by DG and STATCOM respectively. It is observed that equs. (6) and (7) hold good for a distribution system in ref. [62].

$$\sum_{p=1}^{N_{Bus}} P_0 (\left| V_{p\_bus} \right|)^{\alpha_{RLPL}} > P_L \tag{7}$$

$$\sum_{p=1}^{N_{bus}} Q_0 (\left| V_{p\_bus} \right|)^{\beta_{REPL}} > Q_{Loss} \tag{8}$$

2.4 Power system performance indices

(i) Real power loss index (RPLI)

The real power loss index is defined as:

$$RPLI = \frac{RPL\_WDG}{RPL\_WODG} \times 100 \tag{9}$$

The lower value of this index indicates better benefits in terms of real power loss reduction accrued due to DG location & size.

(ii) Reactive Power Loss Index (REPLI)

The reactive power loss index is defined as:

$$REPLI = \frac{REPL\_WDG}{REPL\_WODG} \times 100 \tag{10}$$

The lower values of this index indicate better benefits in terms of reactive power loss reduction accrued due to DG location & size [23-38].

(iii) System power factor (SPF)

The system power factor [24-32] without DG is calculated by equ.(9).

$$SPF\_WODG = \frac{RPL\_WODG}{(RPL\_WODG^2 + REPL\_WODG^2)^{1/2}} \tag{11}$$

The system power factor with DG is calculated based on the DG *i.e.* real and reactive power supplied or absorbed in ref. [27] is given by equ. (10).

$$SPF\_WDG = \frac{RPL\_WODG + RPL\_WDG}{((RPL\_WODG + RPL\_WDG)^2 + (REPL\_WODG \pm REPL\_WDG)^2)^{1/2}} \tag{12}$$

3. GA Implementaion

(i) Introduction to GA: GAs [4-22] is adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. As such they represent an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GAs are by no means random, instead they exploit historical information to direct the search into the region of better performance within the search space. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution; especially those follow the principles first laid down by Charles Darwin of "survival of the fittest". Since in nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones. Reasons for using GA for different types of DGs planning in distribution network environments are as follows [23-28]:

- GA is more reliable than conventional artificial intelligent techniques.
- It is more robust.
- Unlike older AI systems, the GAs do not beak easily even if the inputs changed slightly, or in the presence of reasonable noise.
- GA can quickly scan a vast solution set.
- GA is more robust. So that GA performs very well for large scale optimization problems.
- GA can solve multi-dimensional, non-differential, non-continuous, and even non-parametrical problems.
- GA is a method which is very easy to understand and it practically does not demand the knowledge of mathematics.

The applications of GAs in machine learning, mechanical engineering, electrical engineering, civil engineering, data mining, chemical engineering and image processing, are dealt to make the authors understand where the concept can be applied [29-32].

(ii) Components of GA: Generally GA utilizes three component named as selection, recombination or crossover, and mutation as described in ref. [23-24]. Combinations of these components (selection, crossover and mutation) are called reproduction which is analogous to biological crossover and mutations as described in [22-23]. These operators are explained are as follows [31-32]:

(i) ***Selection operator:*** Reproduction [31-32] consists of selection of chromosomes for the new generation. In the most usual case, the caliber of being suitable of one determines the probability of its endurance for the new generation. There are various selection procedures in GA count on how the endurance values are used. Afterwards the starting value of target function is computed. Correlative to the value of target function the next step of operation selection is compute. The following selection process such as deterministic selection, roulette wheel selection, stochastic selection without substitute, remainder stochastic sampling with substitute, and stochastic sampling with substitute are used in the system. Out of these selections process the roulette selection procedure is followed in this paper since it gives, the quality of being suitable values for each individual values and that is the most important reward, and with that the optimal evaluation in distribution system is perform.

(ii) ***Crossover operator:*** The crossover [31-32] operator is the most important operator of GA. In crossover, generally two chromosomes, called parents, are combined together to form new chromosomes, called offspring. The parents are selected from existing chromosomes in the population with reference towards fitness so that offspring is expected to inherit good genes which make the parents fitter. By iteratively applying the crossover operator, genes of good chromosomes are expected to appear more frequently in the population, eventually leading to convergence to an overall good solution. Crossover probability is taken 0.95.

(iii) Mutation Operator: The mutation [31-38] operator introduces random changes into characteristics of chromosomes. Mutation is generally applied at the gene level. In typical GA implementations, the mutation rate is very small, typically less than 10%. However, the mutation plays a critical role in GA. As discussed earlier, crossover leads the population to converge by making the chromosomes in the population alike. Mutation reintroduces genetic diversity back into the population and assists the search escape from local optima. Mutation probability has taken 0.15.

The flow chart for simulation programming such as GA for optimal sizing and placement of DG with DLMs in ditribution network is shown in Fig. 1.

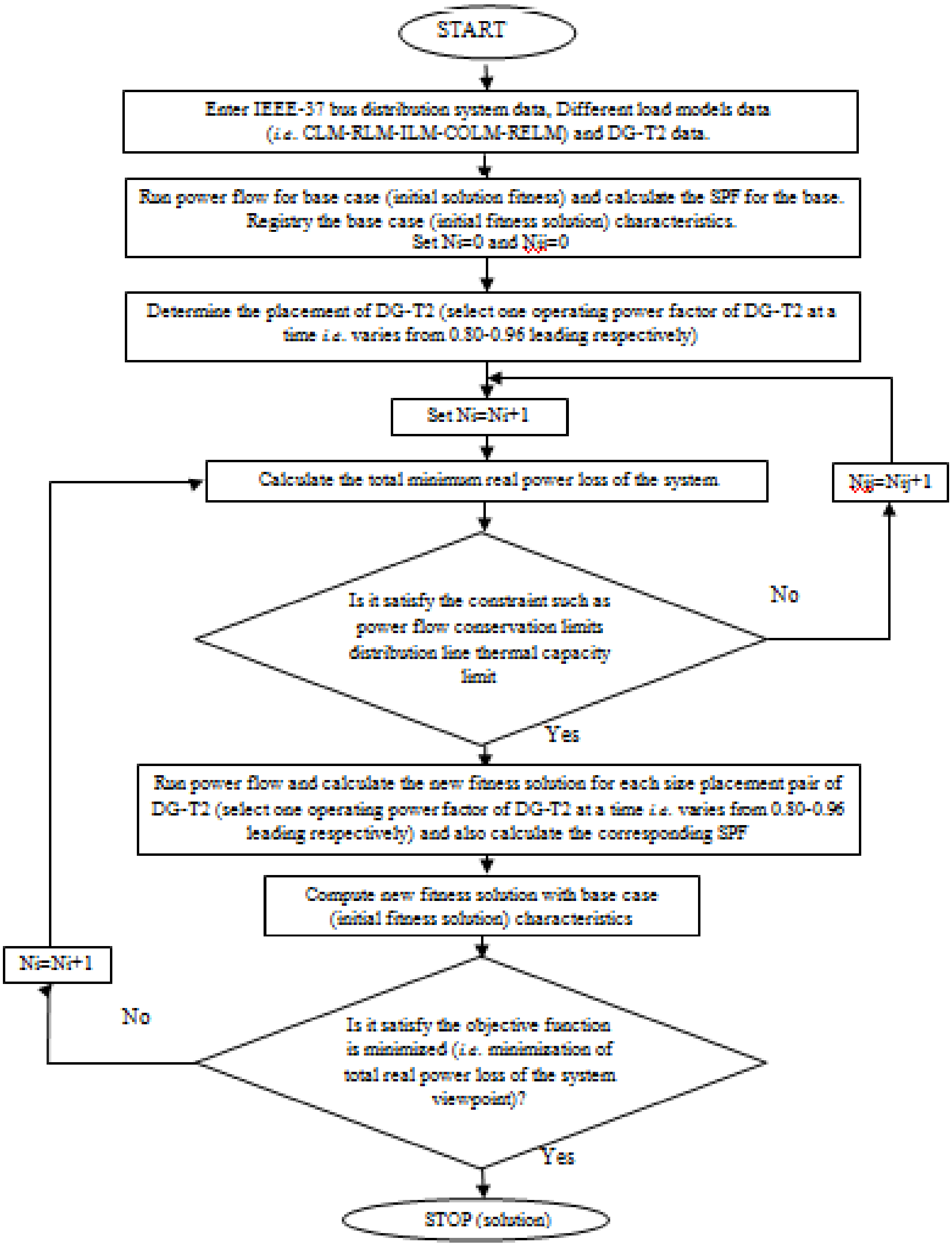

Fig. 1 : Schematic diagram of simulation programming

4. Simulation Results and Discussions

4.1 General

The software is written in MATLAB 2008a computing environment and applied on a 2.63 GHz Pentium IV personal computer with 3 GB RAM. The simulation results and discussions corresponding to DG (DG-T2 type operating at different power factors such as 0.80-0.99 leading, respectively) with DLMs such as constant, industrial, residential, comersial and reference load models are presented as follows. The simulation results and discussions corresponding to DG-T2 type operating at different power factors such as 0.80, 0.83, 0.86, 0.88, 0.94 and 0.96 leading are presented as follows.

4.2 IEEE 37 Bus (38 Node) Test System and its Data

The IEEE-37 bus test system [32] and its data are given in Fig.2 and Table 2 respectively.

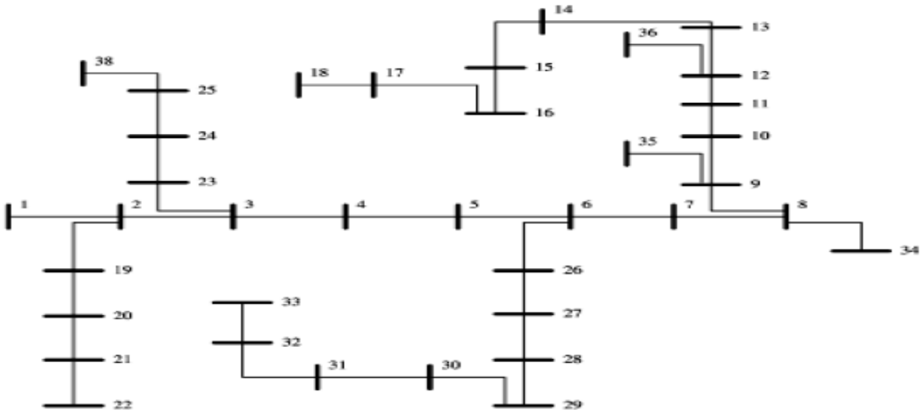

Fig. 2: Single line diagram of the IEEE-37 bus test system.

F	T	Line impedance (p. u.)		L	S_L (p.u.)	Load on the bus (p. u.)	
		R	*X*			*P*	*Q*
1	2	0.000574	0.000293	1	4.60	0.10	0.06
2	3	0.003070	0.001564	6	4.10	0.09	0.04
3	4	0.002279	0.001161	11	2.90	0.12	0.08
4	5	0.002373	0.001209	12	2.90	0.06	0.03
5	6	0.005100	0.004402	13	2.90	0.06	0.02
6	7	0.001166	0.003853	22	1.50	0.20	0.10
7	8	0.004430	0.001464	23	1.05	0.20	0.10
8	9	0.006413	0.004608	25	1.05	0.06	0.02
9	10	0.006501	0.004608	27	1.05	0.06	0.02

10	11	0.001224	0.000405	28	1.05	0.045	0.03
11	12	0.002331	0.000771	29	1.05	0.06	0.035
12	13	0. 009141	0.007192	31	0.50	0.06	0.035
13	14	0.003372	0.004439	32	0.45	0.12	0.08
14	15	0.003680	0.003275	33	0.30	0.06	0.01
15	16	0.004647	0.003394	34	0.25	0.06	0.02
16	17	0.008026	0.010716	35	0.25	0.06	0.02
17	18	0.004538	0.003574	36	0.10	0.09	0.04
2	19	0.001021	0.000974	2	0.50	0.09	0.04
19	20	0.009366	0.008440	3	0.50	0.09	0.04
20	21	0.002550	0.002979	4	0.21	0.09	0.04
21	22	0.004414	0.005836	5	0.11	0.09	0.04
3	23	0.002809	0.001920	7	1.05	0.09	0.05
23	24	0.005592	0.004415	8	1.05	0.42	0.20
24	25	0.005579	0.004366	9	0.50	0.42	0.20
6	26	0.001264	0.000644	14	1.50	0.06	0.025
26	27	0.001770	0.000901	15	1.50	0.06	0.025
27	28	0.006594	0.005814	16	1.50	0.06	0.02
28	29	0.005007	0.004362	17	1.50	0.12	0.07
29	30	0.003160	0.001610	18	1.50	0.20	0.60
30	31	0.006067	0.005996	19	0.50	0.15	0.07
31	32	0.001933	0.002253	20	0.50	0.21	0.10
32	33	0.002123	0.003301	21	0.10	0.06	0.04
8	34	0.012453	0.012453	24	0.50	0.00	0.00
9	35	0.012453	0.012453	26	0.50	0.00	0.00
12	36	0.012453	0.012453	30	0.50	0.00	0.00
18	37	0..003113	0.003113	37	0.50	0.00	0.00
25	38	0.003113	0.002513	10	0.10	0.00	0.00

F = From bus, T = To bus, L = line number, S_L = Line apparent power limit., P = Real power load , Q= Reactive power load

Table 3: Line parameter and load data for 37 buses (38 nodes) test system

4.3 Power factor profile enhancement using DG-T2 at PF 0.80 leading with DLMs

Table 4 (a): Simulation results of DG-T2 (Operating at 0.80 leading power factor)

DLMs	Minloss	DG_MVA	DG_PF	DG_LOC
CLM	0.832	1.7073	0.8	6
ILM	0.096	0.824	0.8	30
RLM	0.113	0.5507	0.8	31
COLM	0.125	2.0704	0.8	23
RELM	0.081	1.6351	0.8	26

Table 4 (b) : Power factor profile for DG-T2 (operating at 0.80 leading power factor)

DLMs	RPL_WODG	RPL_WDG	REPL_WODG	REPL_WDG	RPLI	REPLI	PF_WODG	PF_WDG
CLM	3.9039	1.36584	2.4260	1.02438	34.99	42.23	0.85	0.97
ILM	3.8709	0.65920	2.1674	0.4944	17.03	22.81	0.87	0.94
RLM	3.8304	0.44056	2.2375	0.33042	11.50	14.77	0.86	0.91
COLM	3.7987	1.65632	2.2632	1.24224	43.60	54.89	0.86	0.98
RELM	3.8369	1.30808	2.3678	0.98106	34.09	41.43	0.85	0.97

Table 5 RPL_WODG and RPL_WDG for DG-T2 (Operating at 0.80 leading power factor)

DLMs	RPL_WODG	RPL_WDG
CLM	3.9039	1.36584
ILM	3.8709	0.6592
RLM	3.8304	0.44056
COLM	3.7987	1.65632
RELM	3.8369	1.30808

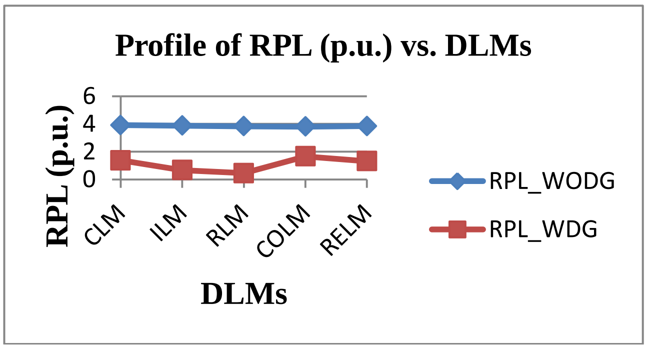

Fig. 3: Profile of RPL (p.u.) vs. DLMs

The real power loss of the systems without DG-T2 and real power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 4.1. From above we observe that every load model, real power loss of the systems with DG-T2 having lesser values as compared to real power loss of the systems without DG-T2.

Table 6:REPL_WODG and REPL_WDG for DG-T2 (Operating at 0.80 leading power factor)

DLMs	REPL_WODG	REPL_WDG
CLM	2.426	1.02438
ILM	2.1674	0.4944
RLM	2.2375	0.33042
COLM	2.2632	1.24224
RELM	2.3678	0.98106

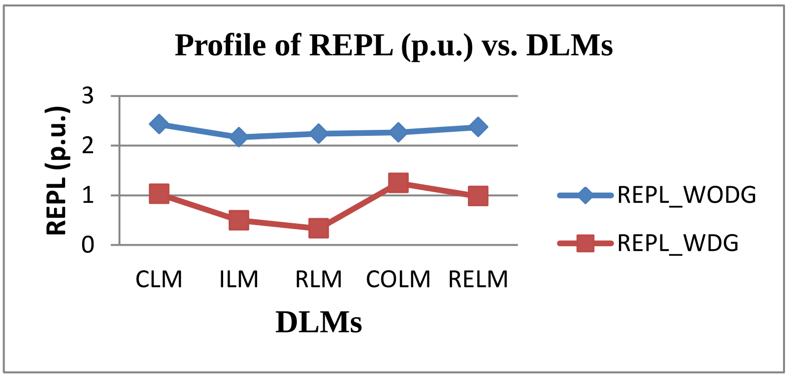

Fig. 4: Profile of REPL (p.u.) vs. DLMs

The reactive power loss of the systems without DG-T2 and reactive power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 4. From above we observe that every load model, reactive power loss of the systems with DG-T2 having lesser values as compared to reactive power loss of the systems without DG-T2.

Table 7: PF_WODG and PF_WDG for DG-T2 (Operating at 0.80 leading power factor)

DLMs	PF_WODG	PF_WDG
CLM	0.85	0.97
ILM	0.87	0.94
RLM	0.86	0.91
COLM	0.86	0.98
RELM	0.85	0.97

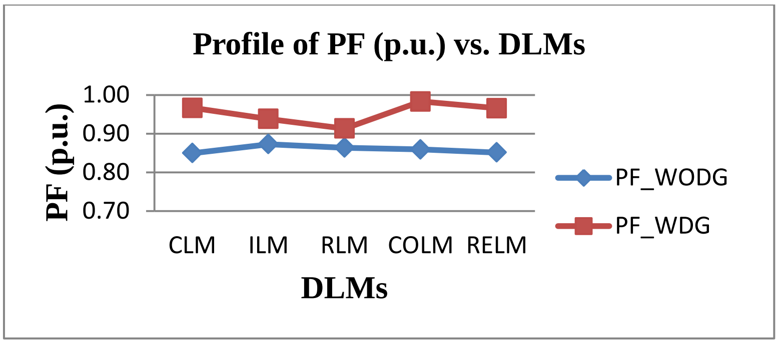

Fig. 5: Profile of PF (p.u.) vs. DLMs

The power factor of the systems without DG-T2 and power factor of the systems with DG-T2 in various operating modes with different load models are shown in fig 5. From above we observe that every load model, power factor of the systems with DG-T2 having larger values as compared to power factor of the systems without DG-T2.

Table 8: RPLI_WODG and RPLI_WDG for DG-T2 (Operating at 0.80 leading power factor)

DLMs	RPLI_WODG	RPLI_WDG
CLM	100	36.20
ILM	100	17.67
RLM	100	13.44
COLM	100	45.99
RELM	100	35.18

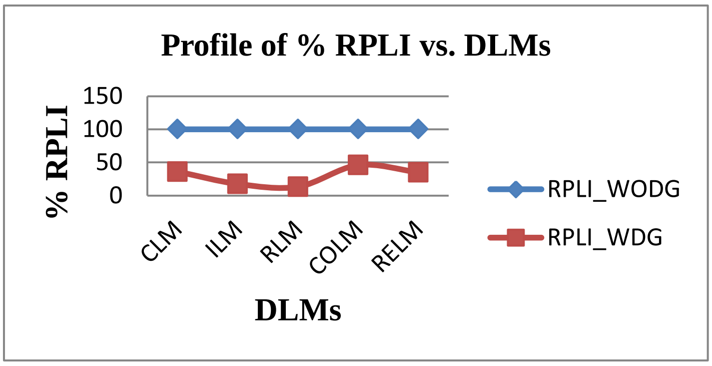

Fig. 6: Profile of % RPLI vs. DLMs

The real power loss index of the systems without DG-T2 and real power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 6. From above we observe that every load model, real power loss index of the systems with DG-T2 having lesser values as compared real power loss index of the systems without DG-T2.

Table 9: REPLI_WODG and REPLI_WDG for DG-T2 (Operating at 0.80 leading power factor)

DLMs	REPLI_WODG	REPLI_WDG
CLM	100	42.23
ILM	100	22.81
RLM	100	14.77
COLM	100	54.89
RELM	100	41.43

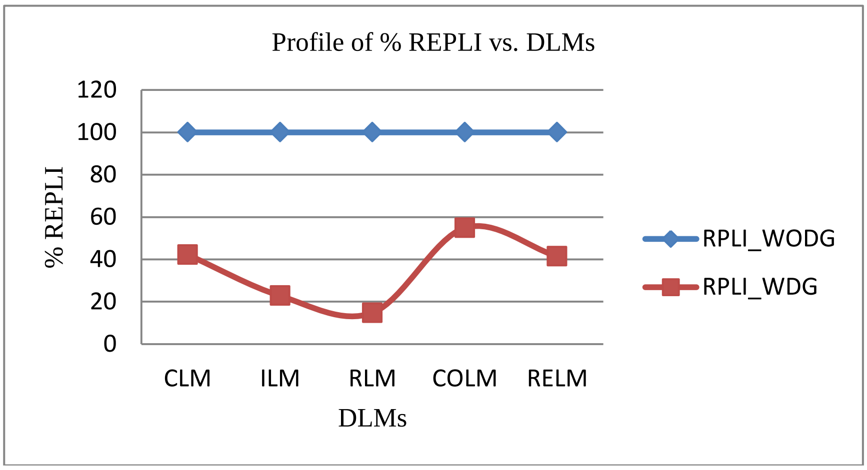

Fig. 7: Profile of % REPLI vs. DLMs

The reactive power loss index of the systems without DG-T2 and reactive power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 7. From above we observe that every load model, reactive power loss index of the systems with DG-T2 having lesser values as compared reactive power loss index of the systems without DG-T2.

4.5 Power factor profile enhancement using DG-T2 at PF 0.83 leading with DLMs

Table 10 (a) Simulation results of DG-T2 (Operating at 0.83 leading power factors)

DLMs	Minloss	DG_MVA	DG_PF	DG_LOC
CLM	0.842	1.7028	0.83	6
ILM	0.096	0.824	0.83	30
RLM	0.109	0.6201	0.83	31
COLM	0.125	2.105	0.83	23
RELM	0.081	1.6263	0.83	26

Table 10 (b): Power Factor Profile for DG-T2 (Operating at 0.83 leading power factor)

DLMs	RPL_WODG	RPL_WDG	REPL_WODG	REPL_WDG	RPLI	REPLI	PF_WODG	PF_WDG
CLM	3.9039	1.41332	2.426	0.949759502	36.20	39.15	0.85	0.96
ILM	3.8709	0.68392	2.1674	0.459597034	17.67	21.20	0.87	0.94
RLM	3.8304	0.51468	2.2375	0.345869079	13.44	15.46	0.86	0.92
COLM	3.7987	1.74715	2.2632	1.174091937	45.99	51.88	0.86	0.98
RELM	3.8369	1.34983	2.3678	0.907090602	35.18	38.31	0.85	0.96

Table 11: RPL_WODG and RPL_WDG for DG-T2 (Operating at 0.83 leading power factor)

DLMs	RPL_WODG	RPL_WDG
CLM	3.9039	1.413324
ILM	3.8709	0.68392
RLM	3.8304	0.514683
COLM	3.7987	1.74715
RELM	3.8369	1.349829

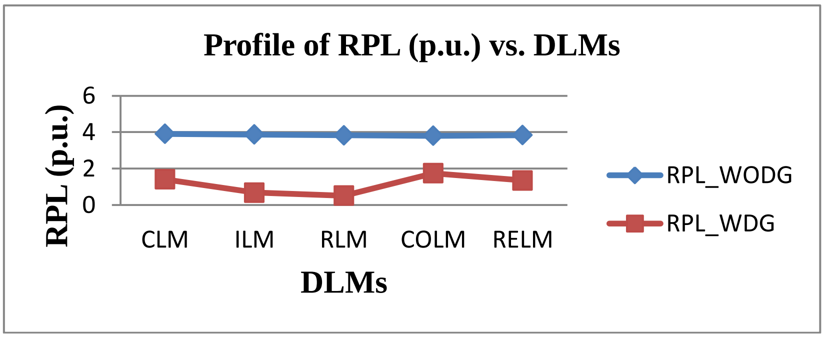

Fig. 8: Profile of RPL (p.u.) vs. DLMs

The real power loss of the systems without DG-T2 and real power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 8. From above we observe that every load model, real power loss of the systems with DG-T2 having lesser values as compared to real power loss of the systems without DG-T2.

Table 12: REPL_WODG and REPL_WDG for DG-T2 (Operating at 0.83 leading power factor)

DLMs	REPL_WODG	REPL_WDG

CLM	2.426	0.949759502
ILM	2.1674	0.459597034
RLM	2.2375	0.345869079
COLM	2.2632	1.174091937
RELM	2.3678	0.907090602

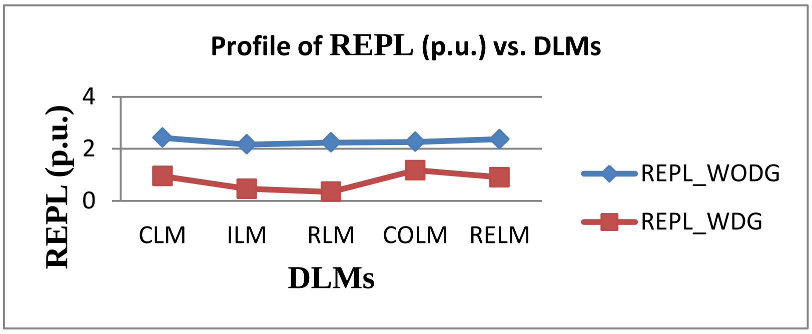

Fig. 9: Profile of REPL (p.u.) vs. DLMs

The reactive power loss of the systems without DG-T2 and reactive power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 9. From above we observe that every load model, reactive power loss of the systems with DG-T2 having lesser values as compared to reactive power loss of the systems without DG-T2.

Table 13: PF_WODG and PF_WDG for DG-T2 (Operating at 0.83 leading power factor)

DLMs	PF_WODG	PF_WODG
CLM	0.85	0.96
ILM	0.87	0.94
RLM	0.86	0.92
COLM	0.86	0.92
RELM	0.86	0.96

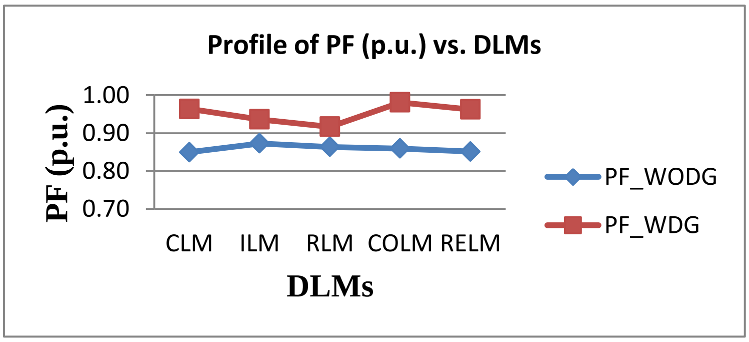

Fig. 10: Profile of PF (p.u.) vs. DLMs

The power factor of the systems without DG-T2 and power factor of the systems with DG-T2 in various operating modes with different load models are shown in fig 10. From above we observe that every load model, power factor of the systems with DG-T2 having larger values as compared to power factor of the systems without DG-T2.

Table 14: RPLI_WODG and RPLI_WDG for DG-T2 (Operating at 0.83 leading power factor)

DLMs	RPLI_WODG	RPLI_WDG
CLM	100	36.20
ILM	100	17.67
RLM	100	13.44
COLM	100	45.99
RELM	100	35.18

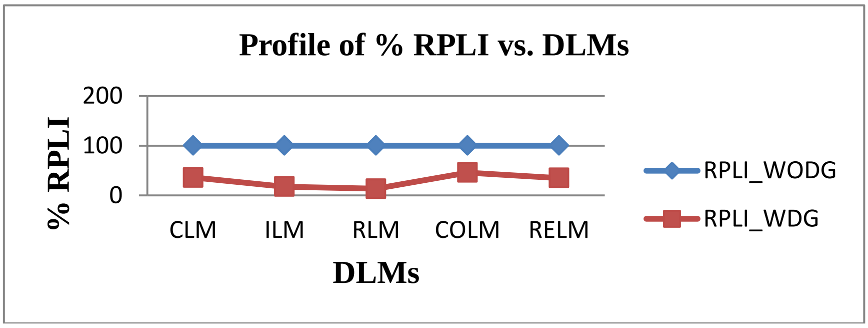

Fig. 11: Profile of % RPLI vs. DLMs

The real power loss index of the systems without DG-T2 and real power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 11. From above we observe that every load model, real power loss index of the systems with DG-T2 having lesser values as compared real power loss index of the systems without DG-T2.

Table 15: REPLI_WODG and REPLI_WDG for DG-T2 (Operating at 0.83 leading power factor)

DLMs	REPLI_WODG	REPLI_WDG
CLM	100	39.15
ILM	100	21.20
RLM	100	15.46
COLM	100	51.88
RELM	100	38.31

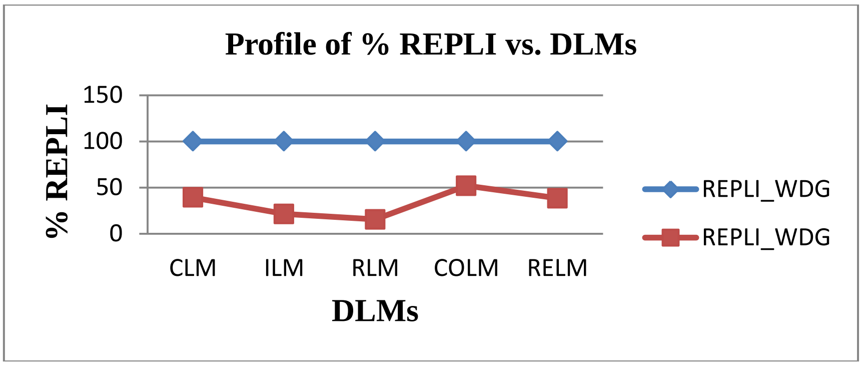

Fig. 12: Profile of % REPLI vs. DLMs

The reactive power loss index of the systems without DG-T2 and reactive power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 12. From above we observe that every load model, reactive power loss index of the systems with DG-T2 having lesser values as compared reactive power loss index of the systems without DG-T2.

4.6: Power Factor Profile Enhancement Using DG-T2 at PF 0.86 Leading with DLMs

Table 16 (a) Simulation results of DG-T2 (Operating at 0.86 leading power factors)

Load Model	Minloss	DG_MVA	DG_PF	DG_LOC
CLM	0.083	1.7073	0.86	6
ILM	0.096	0.8283	0.86	30
RLM	0.114	0.5507	0.86	31
COLM	0.125	2.105	0.86	23
RELM	0.082	1.6175	0.86	26

Table 16 (b): Power Factor Profile for DG-T2 (Operating at 0.86 leading power factor)

DLMs	RPL_WODG	RPL_WDG	REPL_WODG	REPL_WDG	RPLI	REPLI	PF_WODG	PF_WDG
CLM	3.9039	1.46828	2.4260	0.871225002	37.61	35.91	0.85	0.96
ILM	3.8709	0.71234	2.1674	0.422676547	18.40	19.50	0.87	0.93
RLM	3.8304	0.4736	2.2375	0.281018924	12.36	12.56	0.86	0.91
COLM	3.7987	1.8103	2.2632	1.074168939	47.66	47.46	0.86	0.98
RELM	3.8369	1.39105	2.3678	0.825400598	36.25	34.86	0.85	0.96

Table 17: RPL_WODG and RPL_WDG for DG-T2 (Operating at 0.86 leading power factor)

DLMs	RPL_WODG	RPL_WDG
CLM	3.9039	1.468278
ILM	3.8709	0.712338
RLM	3.8304	0.473602
COLM	3.7987	1.8103
RELM	3.8369	1.39105

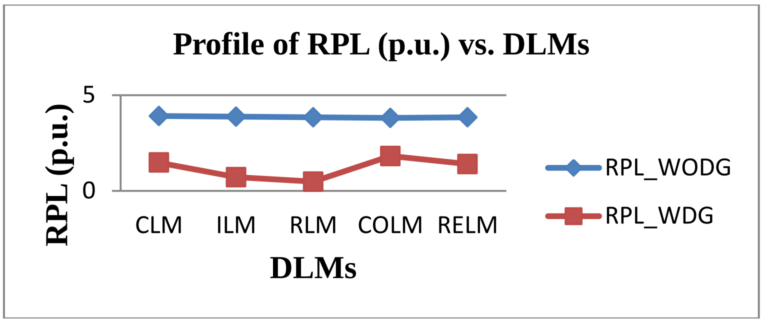

Fig. 13: Profile of RPL (p.u.) vs. DLMs

The real power loss of the systems without DG-T2 and real power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 13. From above we observe that every load model, real power loss of the systems with DG-T2 having lesser values as compared to real power loss of the systems without DG-T2.

Table 18: REPL_WODG and REPL_WDG for DG-T2 (Operating at 0.86 leading power factor)

DLMs	REPL_WODG	REPL_WDG
CLM	2.4260	0.8712
ILM	2.1674	0.4227
RLM	2.2375	0.2810
COLM	2.2632	1.0742
RELM	2.3678	0.8254

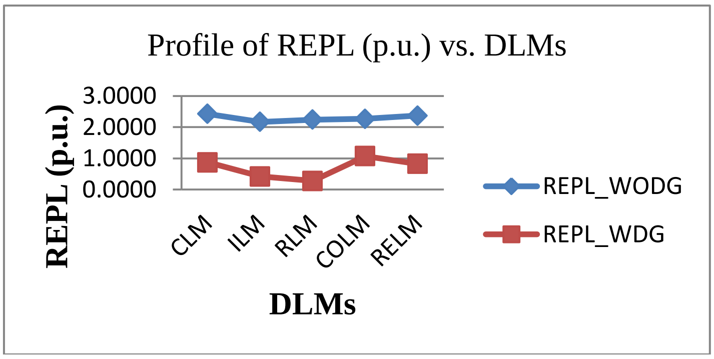

Fig. 14: Profile of REPL (p.u.) vs. DLMs

The reactive power loss of the systems without DG-T2 and reactive power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 14. From above we observe that every load model, reactive power loss of the systems with DG-T2 having lesser values as compared to reactive power loss of the systems without DG-T2.

Table 19: PF_WODG and PF_WDG for DG-T2 (Operating at 0.86 leading power factor)

DLMs	PF_WODG	PF_WDG
CLM	0.85	0.96
ILM	0.87	0.93
RLM	0.86	0.91
COLM	0.86	0.98
RELM	0.85	0.96

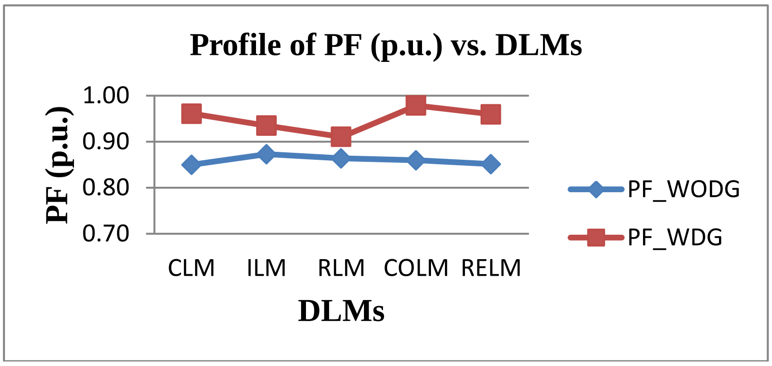

Fig. 15: Profile of PF (p.u.) vs. DLMs

The power factor of the systems without DG-T2 and power factor of the systems with DG-T2 in various operating modes with different load models are shown in fig 15. From above we observe that every load model, power factor of the systems with DG-T2 having larger values as compared to power factor of the systems without DG-T2.

Table 20: RPLI_WODG and RPLI_WDG for DG-T2 (Operating at 0.86 leading power factor)

DLMs	**RPLI_WODG**	**RPLI_WDG**
CLM	100	37.61
ILM	100	18.40
RLM	100	12.36
COLM	100	47.66
RELM	100	36.25

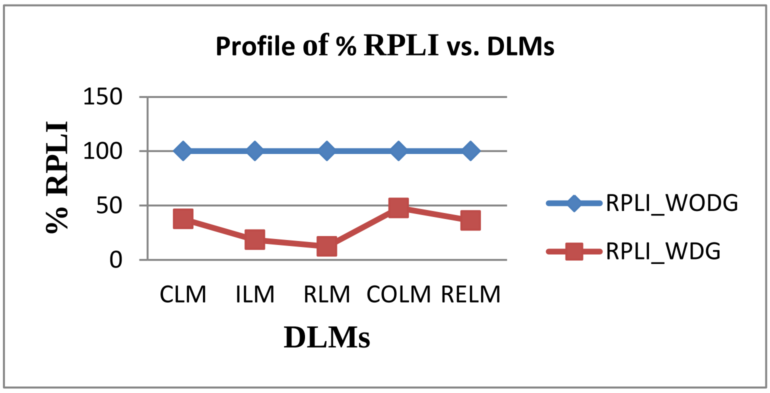

Fig. 16: Profile of % RPLI vs. DLMs

The real power loss index of the systems without DG-T2 and real power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 4.15. From above we observe that every load model, real power loss index of the systems with DG-T2 having lesser values as compared real power loss index of the systems without DG-T2.

Table 21: REPLI_WODG and REPLI_WDG for DG-T2 (Operating at 0.86 leading power factor)

DLMs	REPLI_WODG	REPLI_WDG
CLM	100	35.91
ILM	100	19.50
RLM	100	12.56
COLM	100	47.46
RELM	100	34.86

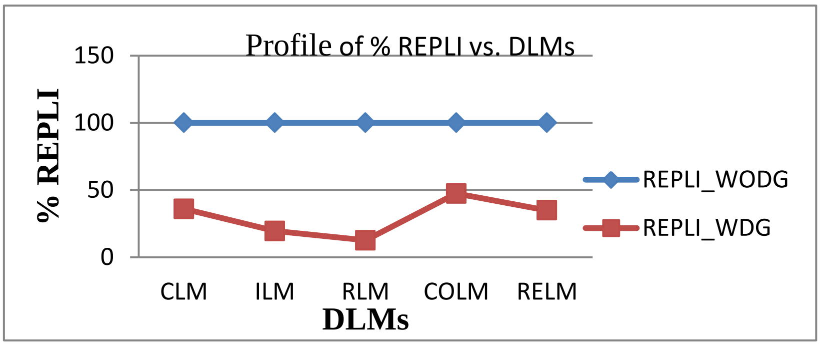

Fig. 17: Profile of % REPLI vs. DLMs

The reactive power loss index of the systems without DG-T2 and reactive power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 17. From above we observe that every load model, reactive power loss index of the systems with DG-T2 having lesser values as compared reactive power loss index of the systems without DG-T2.

4.7 Power factor profile enhancement using DG-T2 at PF 0.88 leading with DLMs

Table 22 (a): Simulation results of DG-T2 (Operating at 0.88 leading power factors)

DLMs	Minloss	DG_MVA	DG_PF	DG_LOC
CLM	0.083	1.7118	0.88	6
ILM	0.097	0.8283	0.88	30
RLM	0.114	0.5507	0.88	31
COLM	0.125	2.105	0.88	23
RELM	0.082	1.6175	0.88	26

Table 22 (b): Power Factor Profile for DG-T2 (Operating at 0.88 leading power factor)

DLMs	RPL_WODG	RPL_WDG	REPL_WODG	REPL_WDG	RPLI	REPLI	PF_WODG	PF_WDG
CLM	3.9039	1.50638	2.4260	0.813059951	38.59	33.51	0.85	0.96
ILM	3.8709	0.7289	2.1674	0.393420702	18.83	18.15	0.87	0.93
RLM	3.8304	0.48462	2.2375	0.261568007	12.65	11.69	0.86	0.91
COLM	3.7987	1.8524	2.2632	0.999819604	48.76	44.18	0.86	0.98
RELM	3.8369	1.4234	2.3678	0.768269933	37.10	32.45	0.85	0.96

Table 23: RPL_WODG and RPL_WDG for DG-T2 (Operating at 0.88 leading power factor)

DLMs	RPL_WODG	RPL_WDG
CLM	3.9039	1.506384
ILM	3.8709	0.728904
RLM	3.8304	0.484616
COLM	3.7987	1.8524
RELM	3.8369	1.4234

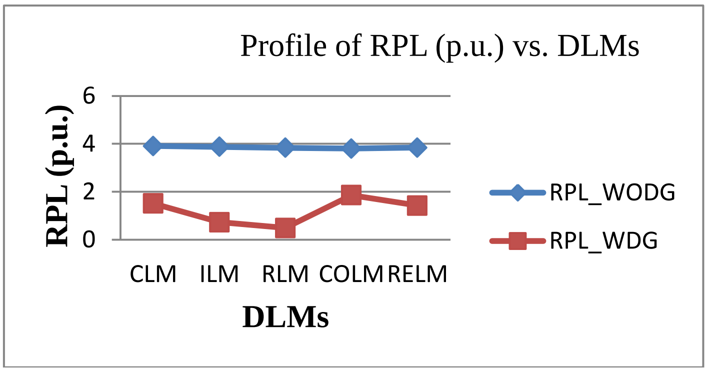

Fig. 18: Profile of RPL (p.u.) vs. DLMs

The real power loss of the systems without DG-T2 and real power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 18. From above we observe that every load model, real power loss of the systems with DG-T2 having lesser values as compared to real power loss of the systems without DG-T2.

Table 24: REPL_WODG and REPL_WDG for DG-T2 (Operating at 0.88 leading power factor)

DLMs	REPL_WODG	REPL_WDG
CLM	2.4260	0.8131
ILM	2.1674	0.3934
RLM	2.2375	0.2616
COLM	2.2632	0.9998
RELM	2.3678	0.7683

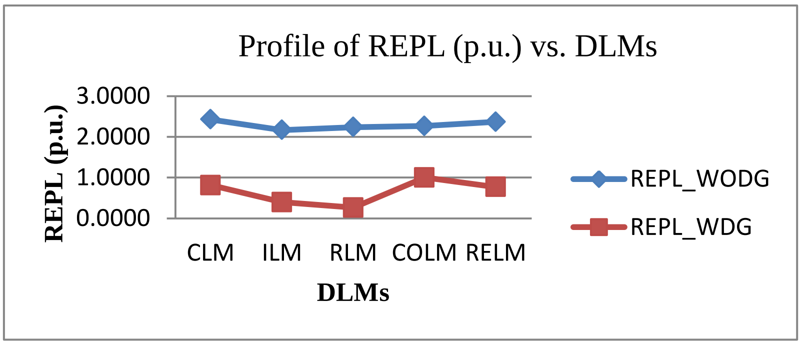

Fig. 19: Profile of REPL (p.u.) vs. DLMs

The reactive power loss of the systems without DG-T2 and reactive power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 19. From above we observe that every load model, reactive power loss of the systems with DG-T2 having lesser values as compared to reactive power loss of the systems without DG-T2.

Table 25: PF_WODG and PF_WDG for DG-T2 (Operating at 0.88 leading power factor)

DLMs	PF_WODG	PF_WDG
CLM	0.85	0.96
ILM	0.87	0.93
RLM	0.86	0.91
COLM	0.86	0.98
RELM	0.85	0.96

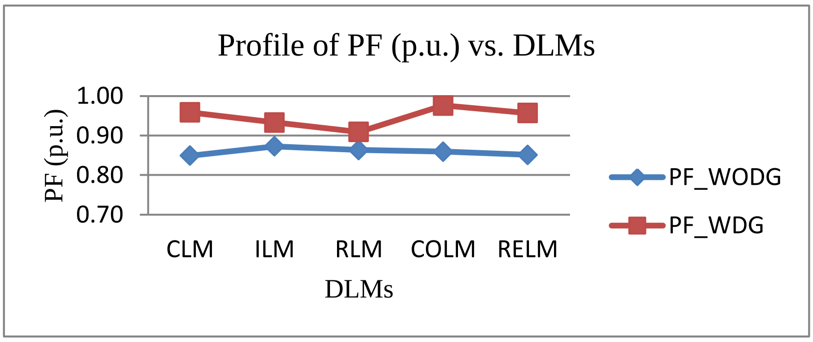

Fig. 20: Profile of PF (p.u.) vs. DLMs

The power factor of the systems without DG-T2 and power factor of the systems with DG-T2 in various operating modes with different load models are shown in fig 20. From above we observe that every load model, power factor of the systems with DG-T2 having larger values as compared to power factor of the systems without DG-T2.

Table 26: RPLI_WODG and RPLI_WDG for DG-T2 (Operating at 0.88 leading power factor)

DLMs	RPLI_WODG	RPLI_WDG
CLM	100	38.59
ILM	100	18.83
RLM	100	12.65
COLM	100	48.76
RELM	100	37.10

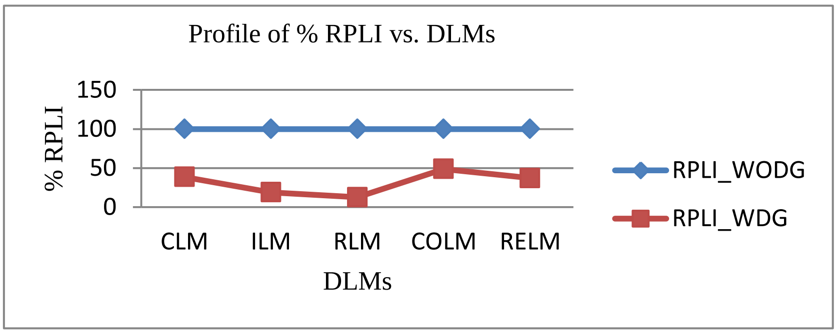

Fig. 21: Profile of % RPLI vs. DLMs

The real power loss index of the systems without DG-T2 and real power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 21. From above we observe that every load model, real power loss index of the systems with DG-T2 having lesser values as compared real power loss index of the systems without DG-T2.

Table 27: REPLI_WODG and REPLI_WDG for DG-T2 (Operating at 0.88 leading power factor)

DLMs	REPLI_WODG	REPLI_WDG
CLM	100	33.51
ILM	100	18.15
RLM	100	11.69
COLM	100	44.18
RELM	100	32.45

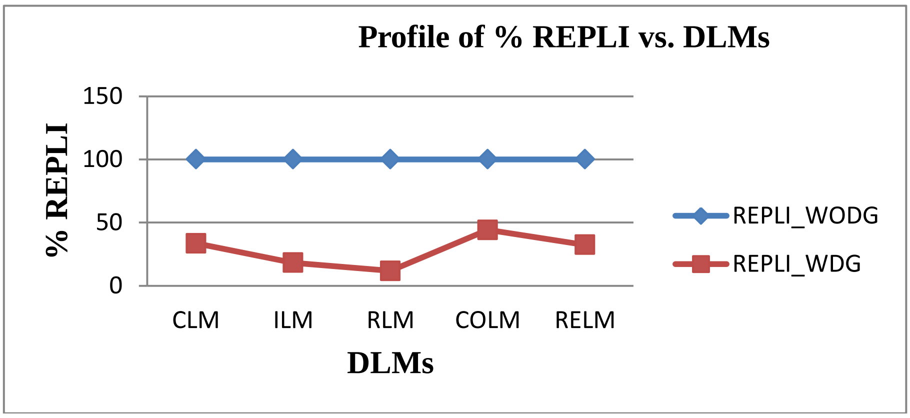

Fig. 22: Profile of % REPLI vs. DLMs

The reactive power loss index of the systems without DG-T2 and reactive power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 22. From above we observe that every load model, reactive power loss index of the systems with DG-T2 having lesser values as compared reactive power loss index of the systems without DG-T2.

4.8 Power factor profile enhancement using DG-T2 at PF 0.94 leading with DLMs

Table 28 (a): Simulation results of DG-T2 (Operating at 0.94 leading power factor)

Load Model	Minloss	DG_MVA	DG_PF	DG_LOC
CLM	0.085	1.7478	0.94	6
ILM	0.1	0.8283	0.94	30
RLM	0.112	0.62	0.94	31
COLM	0.126	2.1007	0.94	23

Table 28 (b): Power Factor Profile for DG-T2 (Operating at 0.88 leading power factor)

DLMs	RPL_WODG	RPL_WDG	REPL_WODG	REPL_WDG	RPLI	REPLI	PF_WODG	PF_WDG
CLM	3.9039	1.64293	2.4260	0.59630469	42.08	24.58	0.85	0.95
ILM	3.8709	0.7786	2.1674	0.28259479	20.11	13.04	0.87	0.93
RLM	3.8304	0.5828	2.2375	0.211528154	15.22	9.45	0.86	0.91
COLM	3.7987	1.97466	2.2632	0.716705151	51.98	31.67	0.86	0.97
RELM	3.8369	1.52872	2.3678	0.554851995	39.84	23.43	0.85	0.95

Table 29: RPL_WODG and RPL_WDG for DG-T2 (Operating at 0.94 leading power factor)

DLMs	RPL_WODG	RPL_WDG
CLM	3.9039	1.642932
ILM	3.8709	0.778602
RLM	3.8304	0.5828
COLM	3.7987	1.974658
RELM	3.8369	1.528722

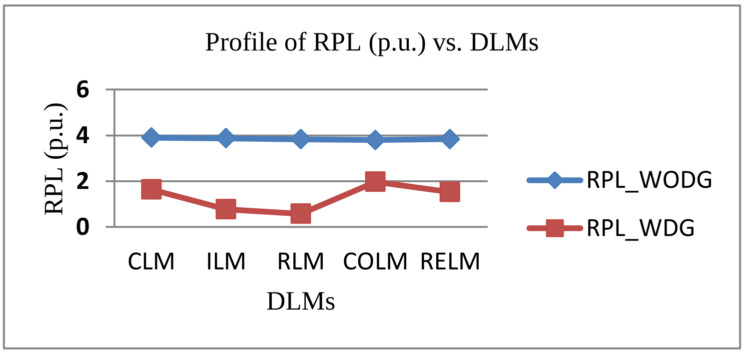

Fig. 23: Profile of RPL (p.u.) vs. DLMs

The real power loss of the systems without DG-T2 and real power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 23. From above we observe that every load model, real power loss of the systems with DG-T2 having lesser values as compared to real power loss of the systems without DG-T2.

Table 30: REPL_WODG and REPL_WDG for DG-T2 (Operating at 0.94 leading power factor)

DLMs	REPL_WODG	REPL_WDG
CLM	2.4260	0.5963
ILM	2.1674	0.2826
RLM	2.2375	0.2115
COLM	2.2632	0.7167
RELM	2.3678	0.5549

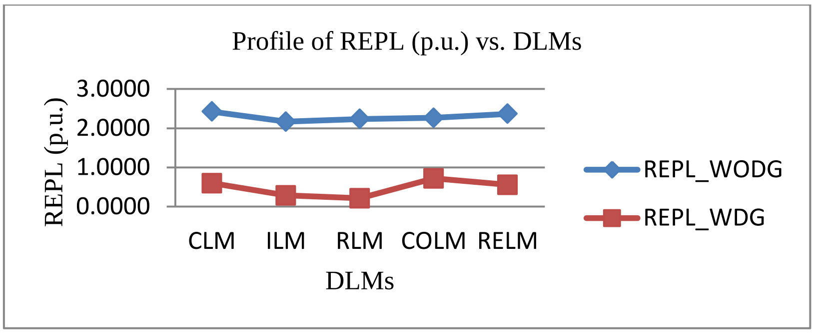

Fig. 24: Profile of REPL (p.u.) vs. DLMs

The reactive power loss of the systems without DG-T2 and reactive power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig 24. From above we observe that every load model, reactive power loss of the systems with DG-T2 having lesser values as compared to reactive power loss of the systems without DG-T2.

Table 31: PF_WODG and PF_WDG for DG-T2 (Operating at 0.94 leading power factor)

DLMs	PF_WODG	PF_WDG
CLM	0.85	0.95
ILM	0.87	0.93
RLM	0.86	0.91
COLM	0.86	0.97
RELM	0.85	0.95

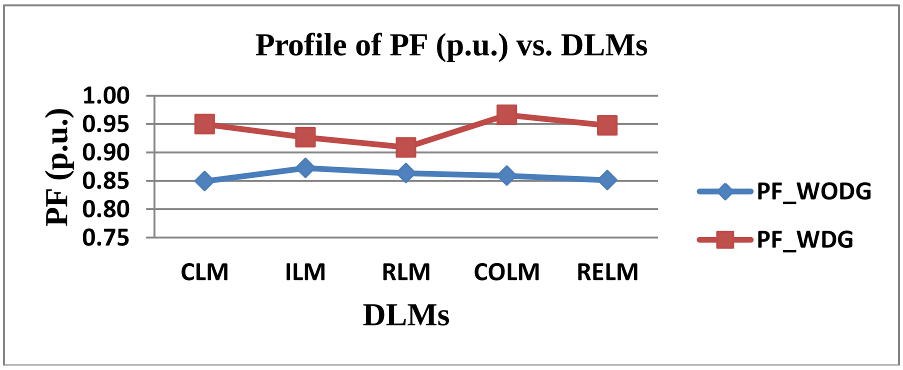

Fig. 25: Profile of PF (p.u.) vs. DLMs

The power factor of the systems without DG-T2 and power factor of the systems with DG-T2 in various operating modes with different load models are shown in fig 25. From above we observe that every load model, power factor of the systems with DG-T2 having larger values as compared to power factor of the systems without DG-T2.

Table 32: RPLI_WODG and RPLI_WDG for DG-T2 (Operating at 0.94 leading power factor)

DLMs	RPLI_WODG	RPLI_WDG
CLM	100	42.08
ILM	100	20.11
RLM	100	15.22
COLM	100	51.98
RELM	100	39.84

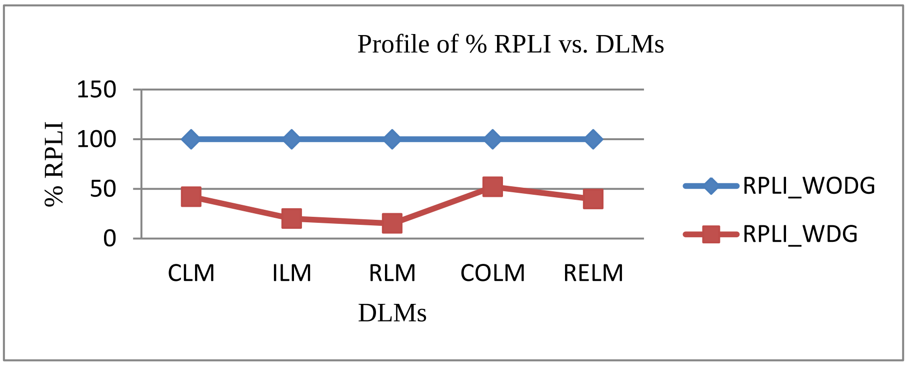

Fig. 26: Profile of % RPLI vs. DLMs

The real power loss index of the systems without DG-T2 and real power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig. 26. From above we observe that every load model, real power loss index of the systems with DG-T2 having lesser values as compared real power loss index of the systems without DG-T2.

Table 33: REPLI_WODG and REPLI_WDG for DG-T2 (Operating at 0.94 leading power factor)

DLMs	REPLI_WODG	REPLI_WDG
CLM	100	24.58
ILM	100	13.04
RLM	100	9.45
COLM	100	31.67
RELM	100	23.43

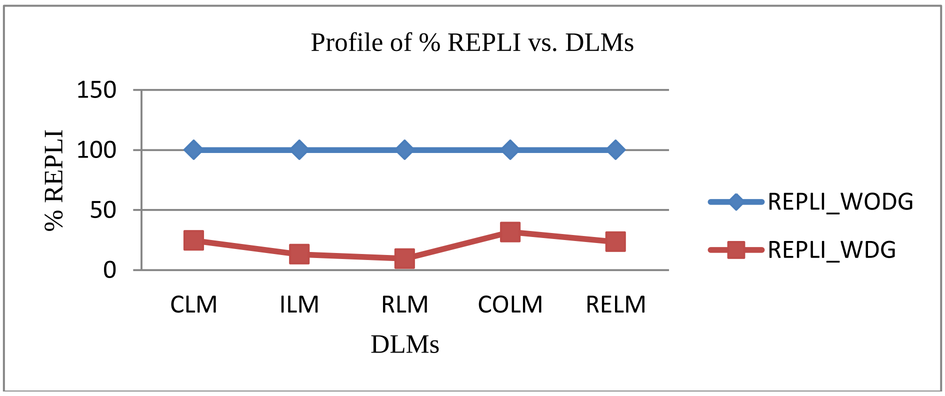

Fig. 27: Profile of % REPLI vs. DLMs

The reactive power loss index of the systems without DG-T2 and reactive power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig. 27. From above we observe that every load model, reactive power loss index of the systems with DG-T2 having lesser values as compared reactive power loss index of the systems without DG-T2.

4.9 Power factor profile enhancement using DG-T2 at PF 0.96 leading with DLMs

Table 34 (a): Simulation results of DG-T2 (Operating at 0.96 leading power factor)

Load Model	Minloss	DG_MVA	DG_PF	DG_LOC
CLM	0.087	1.7747	0.96	6
ILM	0.102	0.8283	0.96	30
RLM	0.118	0.5507	0.96	13
COLM	0.127	2.0877	0.96	23
RELM	0.087	1.6483	0.96	7

Table 34 (b): Power Factor Profile for DG-T2 (Operating at 0.96 leading power factor)

DLMs	RPL_WODG	RPL_WDG	REPL_WODG	REPL_WDG	RPLI	REPLI	PF_WODG	PF_WDG
CLM	3.9039	1.70371	2.4260	0.496916	43.64	20.48	0.85	0.95
ILM	3.8709	0.79517	2.1674	0.231924	20.54	10.70	0.87	0.92
RLM	3.8304	0.52867	2.2375	0.154196	13.80	6.89	0.86	0.90
COLM	3.7987	2.00419	2.2632	0.584556	52.76	25.83	0.86	0.96
RELM	3.8369	1.58237	2.3678	0.461524	41.24	19.49	0.85	0.94

Table 35: RPL_WODG and RPL_WDG for DG-T2 (Operating at 0.96 leading power factor)

DLMs	RPL_WODG	RPL_WDG
CLM	3.9039	1.703712
ILM	3.8709	0.795168
RLM	3.8304	0.528672
COLM	3.7987	2.004192
RELM	3.8369	1.582368

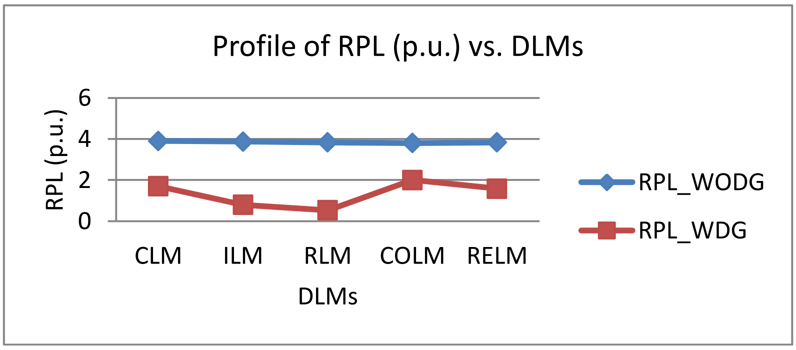

Fig. 28: Profile of RPL (p.u.) vs. DLMs

The real power loss of the systems without DG-T2 and real power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig. 28. From above we observe that every load model, real power loss of the systems with DG-T2 having lesser values as compared to real power loss of the systems without DG-T2.

Table 36: REPL_WODG and REPL_WDG for DG-T2 (Operating at 0.96 leading power factor)

DLMs	REPL_WODG	REPL_WDG
CLM	2.4260	0.4969
ILM	2.1674	0.2319
RLM	2.2375	0.1542
COLM	2.2632	0.5846
RELM	2.3678	0.4615

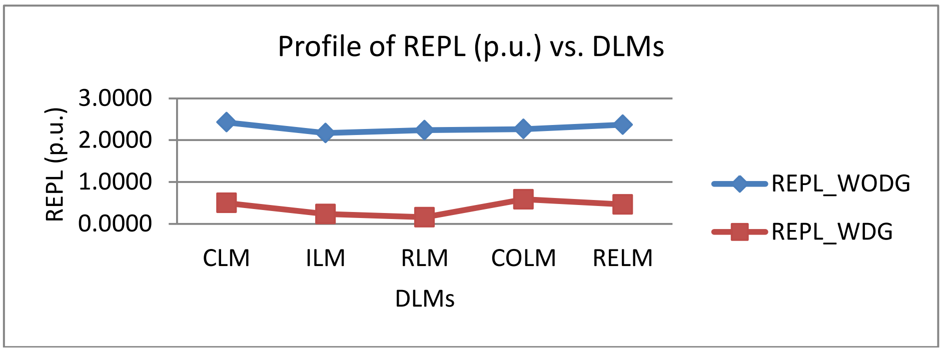

Fig. 29: Profile of REPL (p.u.) vs. DLMs

The reactive power loss of the systems without DG-T2 and reactive power loss of the systems with DG-T2 in various operating modes with different load models are shown in fig. 29. From above we observe that every load model, reactive power loss of the systems with DG-T2 having lesser values as compared to reactive power loss of the systems without DG-T2.

Table 37: PF_WODG and PF_WDG for DG-T2 (Operating at 0.96 leading power factor)

DLMs	PF_WODG	PF_WDG
CLM	0.85	0.95
ILM	0.87	0.92
RLM	0.86	0.90
COLM	0.86	0.96
RELM	0.85	0.94

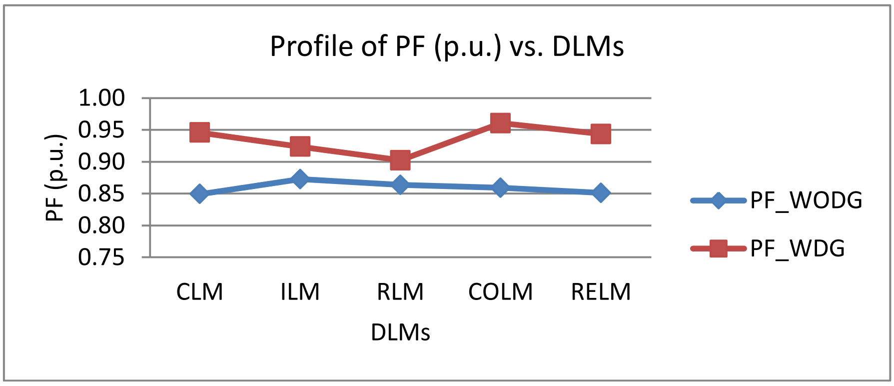

Fig. 30: Profile of PF (p.u.) vs. DLMs

The power factor of the systems without DG-T2 and power factor of the systems with DG-T2 in various operating modes with different load models are shown in fig. 30. From above we observe that every load model, power factor of the systems with DG-T2 having larger values as compared to power factor of the systems without DG-T2.

Table 38: RPLI_WODG and RPLI_WDG for DG-T2 (Operating at 0.96 leading power factor)

DLMs	RPLI_WODG	RPLI_WDG
CLM	100	43.64
ILM	100	20.54
RLM	100	13.80
COLM	100	52.76
RELM	100	41.24

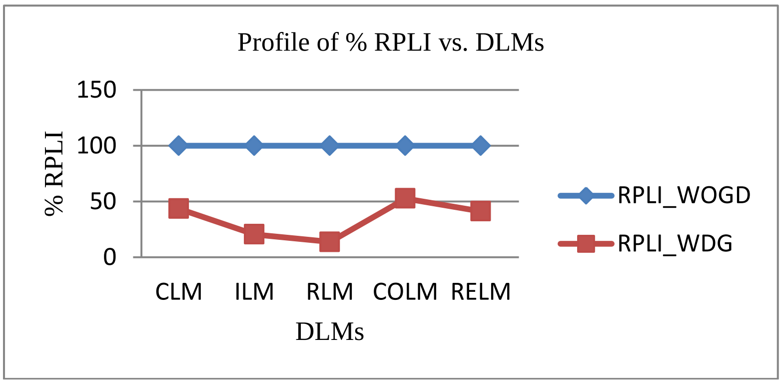

Fig. 31: Profile of % RPLI vs. DLMs

The real power loss index of the systems without DG-T2 and real power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig 31. From above we observe that every load model, real power loss index of the systems with DG-T2 having lesser values as compared real power loss index of the systems without DG-T2.

Table 39: REPLI_WODG and REPLI_WDG for DG-T2 (Operating at 0.96 leading power factor)

DLMs	REPLI_WODG	REPLI_WDG
CLM	100	20.48
ILM	100	10.70
RLM	100	6.89
COLM	100	25.83
RELM	100	19.49

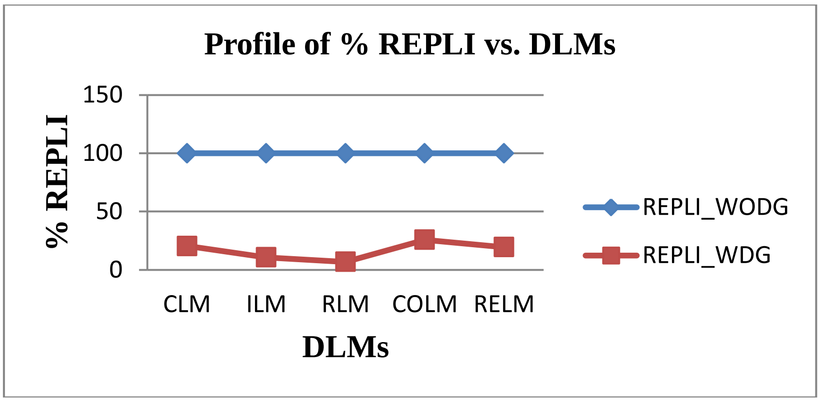

Fig. 32: Profile of % REPLI vs. DLMs

The reactive power loss index of the systems without DG-T2 and reactive power loss index of the systems with DG-T2 in various operating modes with different load models are shown in fig. 32. From above we observe that every load model, reactive power loss index of the systems with DG-T2 having lesser values as compared reactive power loss index of the systems without DG-T2.

4.10: Comparison of RPL (p.u.) vs. DLMs with different operating PF of DG

Table 40: Comparison of RPL (p.u.) at DLMs with different operating PF of DG-T2

DLMs	RPL_WODG	RPL _WDG (0.80 ld)	RPL_ WDG (0.83 ld)	RPL_ WDG (0.86 ld)	RPL _WDG (0.88 ld)	RPL _WDG (0.94 ld)	RPL_ WDG (0.96 ld)
CLM	3.9039	1.36584	1.413324	1.468278	1.506384	1.642932	1.703712
ILM	3.8709	0.6592	0.68392	0.712338	0.728904	0.778602	0.795168
RLM	3.8304	0.44056	0.514683	0.473602	0.484616	0.5828	0.528672
COLM	3.7987	1.65632	1.74715	1.8103	1.8524	1.974658	2.004192
RELM	3.8369	1.30808	1.349829	1.39105	1.4234	1.528722	1.582368

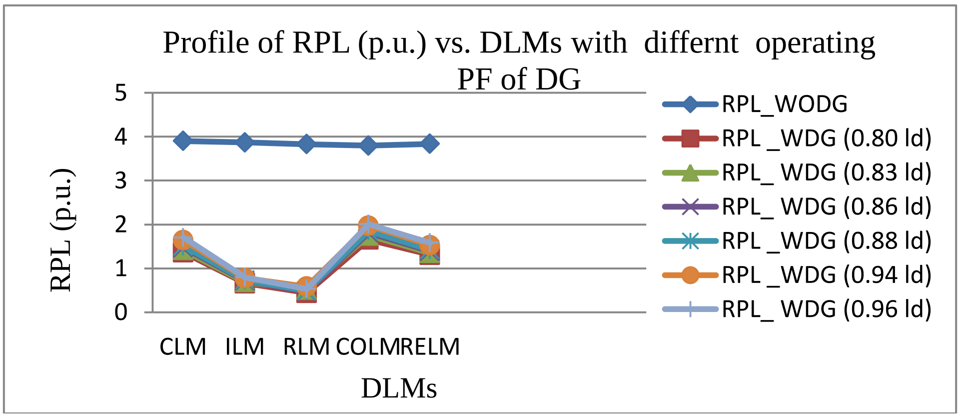

Fig. 33: Comparison of RPL (p.u.) vs. DLMs with different operating PF of DG

From fig. 33, it is shown that with the DLMs with DG T2 at different power factor.

- The Real Power Loss of the system without DG is more as compared to with DG.
- The Real Power Loss of the system increases as the power factor increases.

4.11: Comparison of REPL (p.u.) vs. DLMs with different operating PF of DG

Table 41: Comparison of REPL (p.u.) at DLMs with different operating PF of DG-T2

DLMs	REPL_WODG	REPL _WDG (0.80 ld)	REPL_ WDG (0.83 ld)	REPL_ WDG (0.86 ld)	REPL _WDG (0.88 ld)	REPL _WDG (0.94 ld)	REPL_ WDG (0.96 ld)
CLM	0.8494	0.97	0.96	0.96	0.96	0.95	0.95
ILM	0.8725	0.94	0.94	0.93	0.93	0.93	0.92
RLM	0.8635	0.91	0.92	0.91	0.91	0.91	0.90
COLM	0.8591	0.98	0.98	0.98	0.98	0.97	0.96
RELM	0.8510	0.97	0.96	0.96	0.96	0.95	0.94

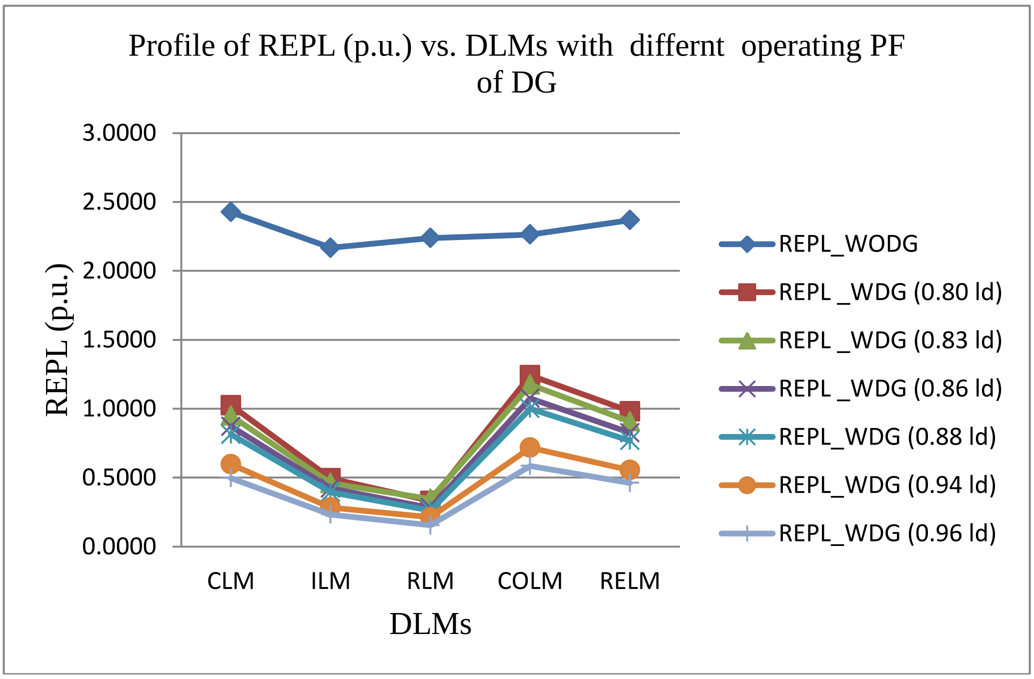

Fig. 34: Comparison of REPL (p.u.) vs. DLMs with different operating PF of DG

From fig. 34, it is shown that with the DLMs with DG T2 at different power factor.

- The Reactive Power Loss of the system without DG is more as compared to with DG.
- The Reactive Power Loss of the system decreases as the power factor increases.

4.12: Comparison of different operating PF of DG vs. DLMs

Table 42: Comparison of different operating PF (with and without DG) vs. DLMs

DLMs	PF_WODG	PF_WDG (0.80 ld)	PF_WDG (0.83 ld)	PF_WDG (0.86 ld)	PF_WDG (0.88 ld)	PF_WDG (0.94 ld)	PF_WDG (0.96 ld)
CLM	0.8494	0.97	0.96	0.96	0.96	0.95	0.95
ILM	0.8725	0.94	0.94	0.93	0.93	0.93	0.92
RLM	0.8635	0.91	0.92	0.91	0.91	0.91	0.90
COLM	0.8591	0.98	0.98	0.98	0.98	0.97	0.96
RELM	0.8510	0.97	0.96	0.96	0.96	0.95	0.94

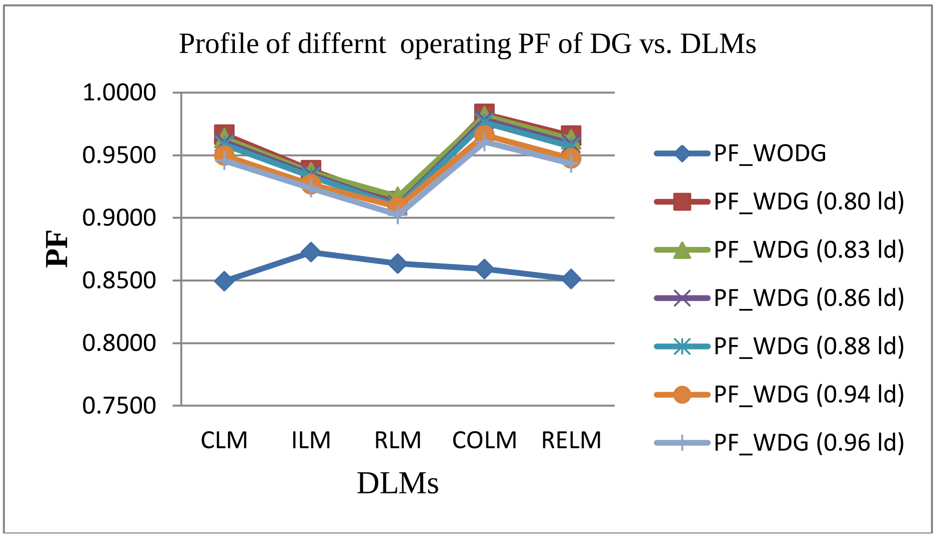

Fig 35: Comparison of different operating PF of DG vs. DLMs

From fig. 35, it is shown that with the DLMs with DG T2 at different power factor.

- The Power Factor of the system without DG has lesser value as compared to with DG.
- The Power Factor of the system decreases as the power factor of DG increases.

4.13 Comparison of RPLI (p.u.) vs. DLMs with different operating PF of DG

Table 43: Comparison of RPLI (p.u.) at DLMs with different operating PF of DG-T2

DLMs	RPLI (0.80 ld)	RPLI (0.83 ld)	RPLI (0.86 ld)	RPLI (0.88 ld)	RPLI (0.94 ld)	RPLI (0.96 ld)
CLM	34.99	36.20	37.61	38.59	42.08	43.64
ILM	17.03	17.67	18.40	18.83	20.11	20.54
RLM	11.50	13.44	12.36	12.65	15.22	13.80
COLM	43.60	45.99	47.66	48.76	51.98	52.76
RELM	34.09	35.18	36.25	37.10	39.84	41.24

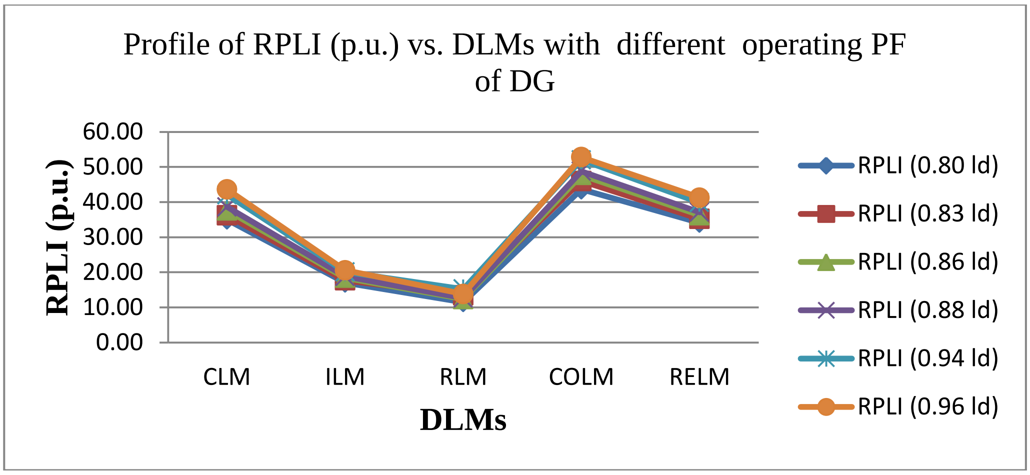

Fig. 36: Comparison of RPLI (p.u.) vs. DLMs with different operating PF of DG

From fig. 36, it is shown that with the DLMs with DG T2 at different power factor.

- The Real power Loss Index of the system has greater value at high power factor.

4.13: Comparison of REPLI (p.u.) vs. DLMs with different operating PF of DG

Table 44: Comparison of REPLI (p.u.) at DLMs with different operating PF of DG-T2

DLMs	REPLI (0.80 ld)	REPLI (0.83 ld)	REPLI (0.86 ld)	REPLI (0.88 ld)	REPLI (0.94 ld)	REPLI (0.96 ld)
CLM	42.23	39.15	35.91	33.51	24.58	20.48
ILM	22.81	21.20	19.50	18.15	13.04	10.70
RLM	14.77	15.46	12.56	11.69	9.45	6.89
COLM	54.89	51.88	47.46	44.18	31.67	25.83
RELM	41.43	38.31	34.86	32.45	23.43	19.49

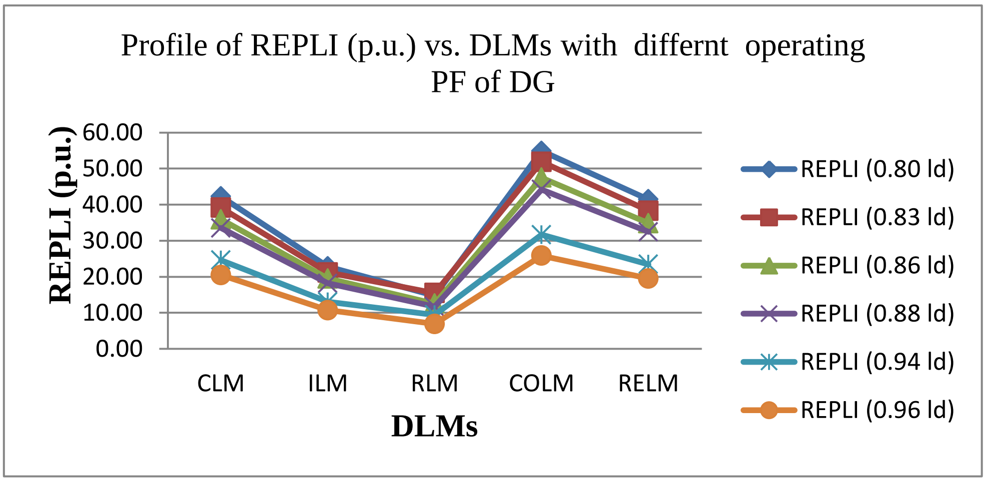

Fig. 37: Comparison of REPLI (p.u.) vs. DLMs with different operating PF of DG

From fig. 37, it is shown that with the DLMs with DG T2 at different power factor.

5. Conclusionsand futurescope of research work

5.1 Conclusions

In this work different load model at every bus for DG-T2 type are considered such as CLM, ILM, RLM, COLM and RELM. The DG planning based on different load models gives appropriate result. It is desirable to keep the DG planning indices i.e. Real power loss index (RPLI), Reactive power loss index (REPLI), below the limits which are defined without DG conditions. By the application of DG the MVA intake power is reduced. The conclusions are as under:

Case (I): Variation of real power loss

- The real power loss of the system without DG is more as compared to with DG.
- The real power loss of the system has high value at higher power factor of DG { *i.e.* RPL_WODG>RPL_WDG (0.96)>RPL_WDG (0.94)>RPL_WDG (0.88)>RPL_WDG (0.86)>RPL_WDG (0.83)> RPL_WDG (0.80)}.

Case (II): Variation of reactive power loss

- The Reactive Power Loss of the system without DG is more as compared to with DG.
- The Reactive Power Loss of the system has lesser value at high power factor of DG {*i.e.* REPL_WODG>REPL_WDG (0.80)>REPL_WDG (0.83)>REPL_WDG (0.86)>REPL_WDG (0.88)> REPL_WDG (0.94)> REPL_WDG (0.96)}.

Case (III): Variation of power factor of the system

- The Power Factor of the system without DG has lesser value as compared to with DG.
- The Power Factor of the system decreases as the power factor of DG increases { *i.e.* PF_WODG<PF_WDG(0.96)<PF_WDG (0.94)<PF_WDG (0.88)<PF_WDG (0.86)<PF_WDG (0.83) <PF_WDG(0.80)}.

Case (IV): Variation of real power loss index

- The Real power Loss Index of the system has greater value at high power factor {*i.e.* RPLI_WDG (0.96)>RPLI_WDG (0.94)>RPLI_WDG (0.88)>RPLI_WDG (0.86)>RPLI_WDG (0.83)> RPLI_WDG (0.80)}.

Case (V): *Variation of reactive power loss index*

- The Reactive Power Loss index of the system has lesser value high power factor {*i.e.* REPLI_WDG (0.80)>REPLI_WDG (0.83)>REPLI_WDG (0.86)>REPLI_WDG (0.88)> REPLI_WDG (0.94)> REPLI_WDG (0.96)}.
- Proper sitting and sizing can reduce losses.
- Size and location pair is different under different load model conditions.
- For DG implementation load models should be taken into account.

5.2 Future scope of work

The following future scopes of this research work in this direction are as follows:

- System of higher no. of buses can be taken.
- Multiple DG planning.
- For any practical system it can be implemented.

- Comparison of different types of DG planning with static as well as realistic load modals by hybrid AI techniques.
- Comparison of different types of DG with static as well as realistic load modals by AI techniques.
- Comparison of different types of DG with static as well as realistic load modals by hybrid AI techniques
- Comparison of different types of DG planning with static as well as realistic load modals by AI techniques.

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