# Allocation of Fixed Costs Considering Distributed Generation and Distinct Approaches of Demand Response Programs in Distribution Networks


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***Abstract*—In the present context the distribution networks are characterized by high presence of Distributed Generation (DG) resources, which imposes important amendments. Moreover, the concept of Demand Response (DR) has also been widely used in electricity markets and smart grids with several benefits. The present paper proposes a methodology that makes possible the allocation of fixed costs in distribution networks considering the integration of DG and DR approaches resources. The consumers can be remunerated through distinct DR approaches, designated by steps, quadratic, constant, linear and elastic. The fixed costs allocation are determined with based on three phases, which includes in first phase a DC Optimal Power Flow (DC-OPF), in second phase a Kirschen's tracing method implementation and, in third phase, the MW-mile method. Case study of the proposed methodology contemplates 49 buses, 47 DG units, 4 external suppliers and 50 consumers, classified into five types.**



***Index Terms*—Demand response programs, distributed generation, fixed costs, kirschen's tracing method, MW-mile.**


## NOMENCLATURE

*Variables*

| | |
|---|---|
| $C_E$ | Elasticity Cost [m.u./kW] |
| $P$ | Power of each resource [kW] |

*Parameters*

| | |
|---|---|
| $C$ | Cost of each resource [m.u./kW] |
| $NC$ | Total number of consumers $c$ |
| $NG$ | Total number of distributed generation $g$ |
| $NSp$ | Total number of suppliers $sp$ |
| $P_{Load}$ | Power scheduled for the consumption [kW] |

*Indexes*

| | |
|---|---|
| $Bus$ | Bus index |
| $c$ | Consumer index |
| $g$ | Distributed generation index |
| $Lines$ | Lines index |
| $sp$ | External supplier index |

*Subscript*

| | |
|---|---|
| *Const; E; L; Q; S* | DR Constant, Elastic, Linear, Quadratic and Steps approaches |
| *DG* | Distributed Generation |
| *Flow* | Power Flow |
| *NSP* | Non-supplied Power |
| *Supplier* | External Supplier |

*Superscript*

| | |
|---|---|
| *a; b; c* | Quadratic, linear and constant coefficient |
| *i; ii; iii* | Each elementary step |
| *Increase* | Maximum resource *E* program |
| *Initial* | Initial resource *E* program |

## I. INTRODUCTION

The current paradigm of exploitation of distribution networks presents a high presence of distributed energy resources, which leads new methodology in the control, operation and management of distribution networks [1]-[2].

The bet in Distributed Generation (DG) brings benefits relative to traditional management of distribution networks, as it can allow the reduction of losses in the lines, as well as having the ability to participate in providing the loads coupled to the electric power system [2]. Also, the implementation of Demand Response (DR) programs can be very useful, namely in competitive environments as are the electricity markets, and in the context of smarts grids [3].


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The two concepts of DG and DR can be associated in order to get the best out, for the operation of the electric power system. In this way, it is required an aggregator entity, designated by Virtual Power Players (VPP), so as to aggregate and manage small-size distributed resources, and thus, be considered in resources scheduling [4].

The development of DR programs should include remuneration models appropriate to each consumer type. In this way, it becomes important to analysis and study models in order to be more attractive. Several studies makes reference to models of different approaches to remunerate consumers, such as logarithmic or exponential models, and based on elasticity models [5]-[7]. However, these models do not include distinctions of DR approaches to different types of consumers, distancing himself from work developed in this paper.

In what concerns the allocation of the operation costs in electrical networks are largely developed and studied for traditional transmission systems [8]-[14]. To allocate the use of network costs there are several methods of charging that can be divided into different categories: Rolled-in methods - allow to get a rate based on the average cost of the system [8]; embedded methods - are based on the analysis of power flow in order to consider the actual use of the power grid [9]; nodal marginal methods - are to assess, at a given moment and a given node marginal prices to long-term and short-term [10]. In addition to the methods that comprise these categories may also be considered as other methodologies, including a hybrid methodology referred to as Amp-mile, which focuses the flow of current to allocate fixed costs of the system [11], and methodology based on game theory, based on the nucleolus and Shapley value approaches [12].

In the traditional system power distribution, the allocation of operation costs are addressed to consumers who are connected to the network, based on the average operation costs [15]. By the presence of distributed energy resources, such as DG and DR resources, the distribution systems configuration has significant differences from traditional systems, specifically, in what concerns to the distinct directions that the power flow can confer [16].

As can see a continued increase in the presence of DG resources and the implementation of DR programs, this paper proposes a methodology that makes possible the allocation of fixed costs in distribution networks, considering the integration of DG and DR resources. The implementation of DR resources are characterized by allow distinct ways of remunerate each consumer, according with characteristics each of them. Each DR approach is appointed by constant, elastic, linear, quadratic and steps, based on previous work [17].

In [13] presents a paper for determining operation costs in the distribution system, which despite consider implementing DR programs in order to remunerate consumers for their participation in DR events, the remuneration approach is similar to any consumer type, distancing himself from work developed in this paper.

The present paper presents a methodology that is able to determine the fixed costs of distribution network, with high presence of DG, DR and external supplier's resources. This methodology is divided into three phases, where the first phase corresponds to the optimal scheduling of the distributed energy resources based on a DC Optimal Power Flow (DC-OPF). In the second phase is determined by Kirschen's tracing method implementation, the resources impact in distribution network. Kirchen's tracing method aims to recover the fixed costs of a transmission system [14]. Finally, it is determined fixed costs based on the MW-mile method.

After this introductory section, Section II details the main contributions of the paper and explains the proposed methodology, which includes the explanation of optimal scheduling, the fixed costs allocation problem in distribution networks, and the details on the tariffs definition. Section III illustrates the case study and Section IV includes the obtained results. Finally, Section V presents the main conclusions of the work.

## II. METHOD OF FIXED COSTS ALLOCATION WITH DR APPROACHES

In this section is presented in detail the proposed methodology for allocation the fixed costs of a distribution network, considering several DR approaches.

The proposed methodology in this paper aims to allocate fixed costs of a distribution network, considering high penetration of DG, external suppliers, as well as the implementation of DR through five distinct remuneration approaches. As there are different types of consumers, it is necessary to develop remuneration models that suit each consumer, which by nature have different characteristics. This methodology consists of three different phases, explained in detail, each of them, in sub-sections that follow: II-A (Phase 1 – Optimal Resources Scheduling), II-B (Phase 2 – Kirschen's Tracing Method) and II-C (Phase 3 – Fixed Costs Allocation).

In Fig. 1 shows the diagram that explains the methodology proposed to allocate fixed costs related to the operating costs of a distribution system.

As can be seen in Fig. 1, in this methodology is taken into account the data on the characteristics of producers and consumers of energy present in the distribution system, as well as characteristics of the branches that constitute the distribution network. Each consumer can participate in DR programs, being the limits defined that each consumer can attend in DR events. In addition, demand forecast is considered, generation costs and the costs of each DR approach.

Modelling of consumers includes five different types of remuneration, designated by constant, elastic, linear, quadratic and steps. Several scenarios can be developed through the implementation of five distinct DR approaches, these can be implemented individually or simultaneously.

The proposed methodology is innovative and provides the following contributions:

- Determination of fixed costs of a distribution network, considering the high presence of DG resources, and implementation of distinct DR approaches;

- Modelling of five distinct types of DR programs (constant, elastic, linear, quadratic and steps), for the remuneration of consumers;
- Use of Kirschen's tracing method to determine the impacts of each resource in the distribution network and use of a variant of the MW-Mile method for allocation of fixed costs for each resource;
- Ascertain the contribution of DR approaches have in the fixed costs allocation, evaluating the impact of each approach, when these approaches are applied individually or simultaneously.

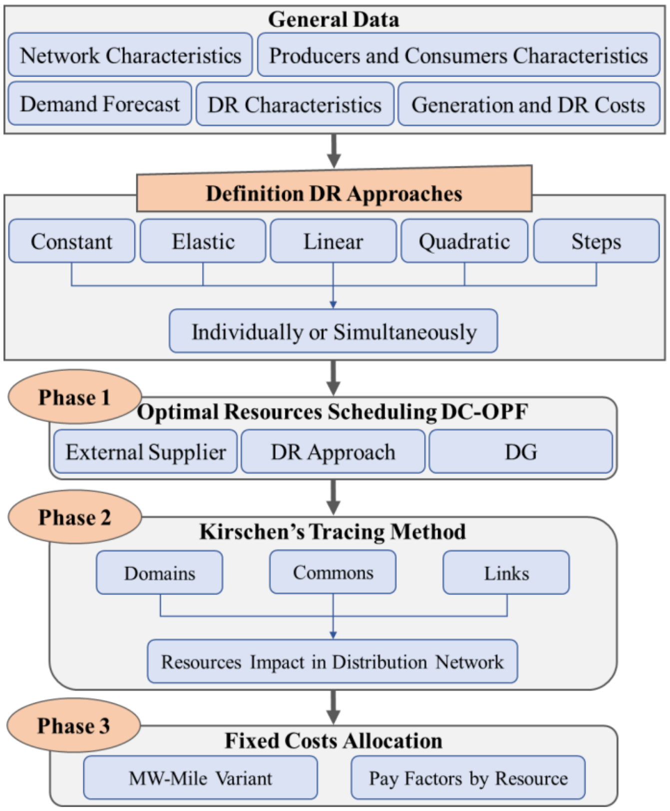


Figure 1. Diagram of the proposed methodology.

### A. *Optimal Resources Scheduling*

The first phase corresponds to the optimal scheduling of distributed energy resources, which includes a DC-OPF, and it is obtained from the information of distributed energy resource and network data, as well as the definition of the DR approach. The optimal resources scheduling aims to minimize operation costs of the electrical power system, given by (1).

Equation (1) allows clarify the different characteristics of each DR approach implemented. These different approaches were developed in a previous work, in [17]. As consumers have different characteristics, it is expected that expectations of remuneration for participation in DR programs are distinct among the different consumers' types. Thus several approaches are developed to allow developing different ways to remunerate consumers.

$$
\text{Minimize } OC = \left[ \begin{array}{l} \sum_{sp=1}^{NSp} \left( P_{Supplier(sp)} \times C_{Supplier(sp)} \right) + \sum_{g=1}^{NG} \left( P_{DG(g)} \times C_{DG(g)} \right) \\ + \sum_{c=1}^{NC} \left[ \begin{array}{l} \left( P^{i}_{S(c)} \times C^{i}_{S(c)} + P^{ii}_{S(c)} \times C^{ii}_{S(c)} + P^{iii}_{S(c)} \times C^{iii}_{S(c)} \right) \\ + \left( P^{2}_{Q(c)} \times C^{a}_{Q(c)} + P_{Q(c)} \times C^{b}_{Q(c)} \right) \\ + \left( P_{Const(c)} \times C_{Const(c)} \right) \\ + \left( P_{L(c)} \times C^{b}_{L(c)} + C^{c}_{L(c)} \right) \\ + \left[ \left( P^{Initial}_{E(c)} - P_{E(c)} \right) \times \left( C^{Initial}_{E(c)} + C^{Increase}_{E(c)} \right) \right] \\ + \left( P_{NSP(c)} \times C_{NSP(c)} \right) \end{array} \right] \end{array} \right] \quad (1)
$$

One of the approaches available is called by DR steps ("*S*"), on which the consumer is remunerated by three prices (*i*, *ii*, *iii*) that correspond to each of the three consumption reduction levels that each consumer can effect, i.e. each consumption reduction level has an associate a particular price.

The DR quadratic ("*Q*") approach presents a quadratic trend to remunerate consumers who participate in DR programs whose form of remuneration follows this approach. As such, this approach includes quadratic (*a*) and linear (*b*) coefficients, as identified in (1).

The two approaches, designated DR constant ("*Const*") and DR linear ("*L*"), have very similar characteristics, contemplating a price stipulated to remunerate consumers for the amount of reduced consumption, this price is independent of the amount used. However, DR linear approach also has fixed price, representing a constant coefficient (*c*). Lastly, the DR elastic ("*E*") approach depends on the amount used and the price for such use.

Several constraints are considered in optimization resource problem. In (2), the electric power system balance constraint is shown.

$$
\sum_{sp \in \Omega^{Sp}_{Bus}} P_{Supplier(sp)} + \sum_{g \in \Omega^{G}_{Bus}} P_{DG(g)} + \sum_{w \in \Omega^{Lines}_{Bus}} P_{Flow(w)} + \sum_{c \in \Omega^{C}_{Bus}} \left[ \begin{array}{l} P^{i}_{S(c)} + P^{ii}_{S(c)} \\ + P^{iii}_{S(c)} + P_{Const(c)} \\ + P_{Q(c)} + P_{L(c)} \\ + P_{E(c)} + P_{NSP(c)} \end{array} \right] - \sum_{c \in \Omega^{C}_{Bus}} P_{Load(c)} = 0 \;\; , \forall Bus \quad (2)
$$

This constraint ensures that each bus the consumption is satisfied, this way, it takes into consideration the coupled generation in each bus, the forecast consumption, consumption reduction by implementing DR programs, as well as the power flow that flows in each branch, i.e. which entering and leaving on each bus.

The full formulation of the problem includes limitations that are imposed to power and price of each resource (suppliers, producers and consumers), and the branch thermal limits. For each consumer is established maximum limit which can reduce consumption, in each DR approach. In addition, for each DR program is imposed a maximum limit of participation, both individually and as the sum of the participation of all DR programs are instituted a maximum reduction of consumption, considering the participation of each consumer.

The resources schedule optimization has been implemented and solved in TOMLAB [18].

### B. *Kirschen's Tracing Method*

In the second phase is determined the impact that each resource has in each branch of the network, through the use of Kirschen's tracing method. This method is based on the information of the location of producers and consumers electricity in the network, as well as the power flow that flows in each branch of the network. This technique is based on a set of definitions: Domains - set of buses receiving power from a given generator; Commons - set of adjacent buses receiving power from the same set of generators; Links - lines that connect with the commons [14].

The method can be applied to all distributed energy resources, including generation and consumption resources. Thus, based on these three definitions, the system is simplified, being determined by the proportional sharing principle, the impact of each resource. For this reason, the results can be imperfect, especially because the operation of the distribution network is characterized by several variations of the direction of power flow.

### C. *Fixed Costs Allocation*

The third phase corresponds to the determination of fixed costs are based on a variant of the MW-mile method [9],[19], which has as characteristics consider the power flow that flows in each branch. The fixed costs of a network relate to the operation and maintenance costs, and also considers the costs associated with network initial investment.

In (3) shows the equation that allows allocate fixed costs that should be borne by DG and suppliers. Fixed costs to be allocated to the loads are determined in (4), and (5) shows the allocation of fixed costs for the DR constant approach, but for the others approaches used expression is similar. Equation (6) ensures that payment of the total fixed costs is made, by distributing the costs by the all distributed energy resources. Thus, the sum of the three pay factors must be equal to 1.

$$C^F_{(k,j,g)} = \frac{PF_{(k,j,g)} \times C^F_{(k,j)}}{PF_{(k,j)}} \times X_{Generation} \tag{3}$$

$$C^F_{(k,j,load)} = \frac{PF_{(k,j,load)} \times C^F_{(k,j)}}{PF_{(k,j)}} \times X_{Load} \tag{4}$$

$$C^F_{(k,j,Const)} = \frac{PF_{(k,j,Const)} \times C^F_{(k,j)}}{PF_{(k,j)}} \times X_{DR} \tag{5}$$

$$X_{Generation} + X_{Load} + X_{DR} = 1 \tag{6}$$

Where:

| | |
|---|---|
| $C^F_{(k,j)}$ | Fixed costs of branch j-k [m.u./h] |
| $C^F_{(k,j,Const)}$ | Fixed costs allocated for DR constant [m.u./h] |
| $C^F_{(k,j,g)}$ | Fixed costs allocated for generation [m.u./h] |
| $C^F_{(k,j,load)}$ | Fixed costs allocated for load [m.u./h] |
| $PF_{(k,j)}$ | Power flow that flows in branch k-j [kW] |
| $PF_{(k,j,Const)}$ | Contribution that the DR constant approach has in branch k-j [kW] |
| $PF_{(k,j,g)}$ | Contribution that the generation has in branch k-j [kW] |
| $PF_{(k,j,load)}$ | Contribution that the load has in branch k-j [kW] |
| $X_{Generation}$ | Generation pay factor |
| $X_{DR}$ | DR pay factor |
| $X_{Load}$ | Load pay factor |

## III. Case Study

This section presents the case study, which can implement the proposed methodology. The Fig. 2 illustrates the case study which was based on [20], however was only considered the Feeder 5.

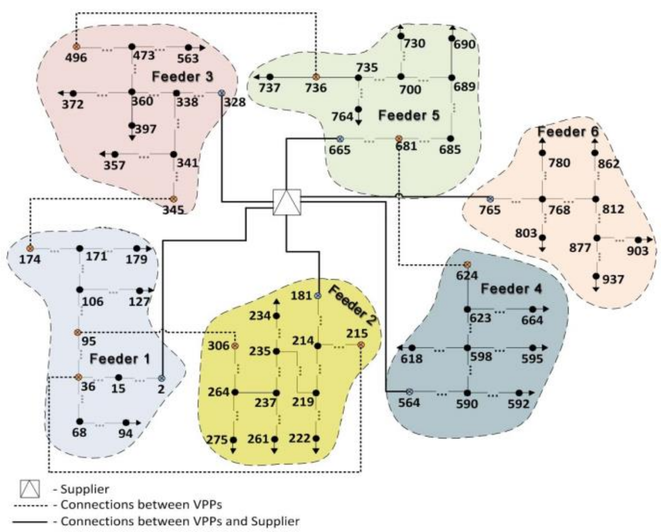


Figure 2. Distribution network [20].

Moreover, the Feeder 5 configuration has been adapted in order to consider that distributed energy resources are located in the main feeder taking advantage of the better performance Kirschen's tracing method.

The case study includes 49 buses, 47 DG units, 4 external suppliers, and 50 consumers, classified into 5 types in particular, Domestic (DM), Small Commerce (SC), Medium Commerce (MC), Large Commerce (LC), and Industrial (I).

The Fig. 3 identifies in detail the consumption of each type of consumer, as well as the number of consumers of each type present in the case study. The total of consumption is 5111 kW.

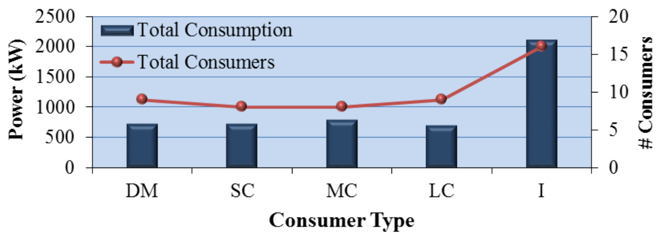


Figure 3. Total consumption and consumers by each type.

Each of the types of consumers that are present in this case study can be associated with distinct DR approaches, these may be applied individually or simultaneously, allowing the development of several scenarios.

When DR approaches are implemented individually can be applied to any type of consumer, yet when the approaches are implemented simultaneously, each consumer type can only be associated with two distinct DR approaches at the same time. As such, the Domestic (DM) and Small Commerce (SC) can be associated with the DR constant and linear approaches, the Medium Commerce (MC) can be related to DR linear and steps approaches, the Large Commerce (LC) and Industrial (I) can be combined with DR steps and quadratic approaches.

In this case study each consumer can only reduce up to 40% of their initial consumption, as well as each DR approach. When implemented simultaneously, can only contribute up to 40% of total consumption reduced by all DR approaches, and for DR elastic approach is considered in minimum 5% of its participation of total consumption reduced by all DR approaches.

Table I identifies the prices applied to each DR approach in accordance with the type of consumer associated [17].

TABLE I. PRICES BY CONSUMER AND DR APPROACHES TYPES.

| **Prices *(m.u./kWh)*** | | **DM** | **SC** | **MC** | **LC** | **I** |
|---|---|---|---|---|---|---|
| **Constant** | | 0.20 | 0.16 | 0.19 | 0.18 | 0.14 |
| **Linear** | ***b*** | 0.1980 | 0.1584 | 0.1881 | 0.1782 | 0.1386 |
| | ***c*** | 0.0020 | 0.0016 | 0.0019 | 0.0018 | 0.0014 |
| **Quadratic** | ***a*** | 0.000020 | 0.000016 | 0.000019 | 0.000018 | 0.000014 |
| | ***b*** | 0.20 | 0.16 | 0.19 | 0.18 | 0.14 |
| **Steps** | ***i*** | 0.16 | 0.15 | 0.18 | 0.17 | 0.17 |
| | ***ii*** | 0.20 | 0.19 | 0.20 | 0.24 | 0.26 |
| | ***iii*** | 0.24 | 0.22 | 0.26 | 0.26 | 0.28 |
| **Elastic *(Initial Price)*** | | 0.18 | 0.19 | 0.20 | 0.16 | 0.12 |

In what concerns the generation data of the several DG technologies and external suppliers, Table II shows the characteristics and prices of each them.

TABLE II. GENERATION CHARACTERISTICS AND PRICES.

| **Type of generator** | **# Units** | **Total capacity *(kW)*** | **Min price *(m.u./kWh)*** | **Max price *(m.u./kWh)*** |
|---|---|---|---|---|
| **Photovoltaic** | 18 | 610 | - | 0.20 |
| **CHP** | 1 | 1000 | - | 0.08 |
| **Small Hydro** | 2 | 7 | - | 0.03 |
| **Wind** | 22 | 508 | - | 0.045 |
| **Biomass** | 2 | 226 | - | 0.15 |
| **WtE** | 1 | 8 | | 0.11 |
| **Fuel Cell** | 1 | 189 | | 0.30 |
| **External Supplier** | 4 | 6500 | 0.03 | 0.35 |
| **Total** | 51 | 9048 | - | - |

CHP – Combined Heat Power

WtE – Waste-to-Energy

The allocation of fixed costs of the distribution network is necessary to consider pay factors, which allows distribute the costs for several resources types. In this case study was considered an equitable distribution between the generation of resources and consumption, considering that the generation resources, includes DG, external suppliers and DR ($X_{Generation} + X_{DR}$), must allocate 50% of total fixed costs, and consumption resources ($X_{Load}$) must supporting the remaining 50%. For each branch is assumed that the fixed cost is 2,083 m.u./h, and this case study only takes into account the allocation of fixed costs given for a given period (hour) of operation of the distribution network.

The focus of this case study is to develop two scenarios, which correspond to distinct ways of DR approaches as well as these are implemented, namely, individually or simultaneously, allowing determine their influence on the allocation of fixed costs of the distribution network. The high presence of distributed energy resources, including several types of DG technologies are considered.

## IV. RESULTS

The present section illustrates some examples of the results obtained by the application of the proposed methodology. The results present two scenarios developed, which correspond to two different implementations of DR approaches. In sub-section IV-A shows the allocation of fixed costs with the implementation of DR approaches individually, and in sub-section IV-B shows the results for the determination of fixed network costs with the implementation of DR approaches simultaneously. The use of DR occurs when resources brings economic advantages in operating costs.

### A. *Fixed costs allocation with DR approaches individually*

As mentioned in section IV, the total fixed costs are divided equally among the generation resources (DG, external suppliers and DR) by 50%, and the remaining 50% allocated to consumption resources. In this way, the Fig. 4 and Fig.5

identifies, respectively, the fixed costs allocation by each generation resources and by each consumption resources.

Fig. 4 shows for each DR approach implemented individually, the percentage allocated to each type generation resources, which includes DR. As can be seen, for scenarios that are implemented DR constant, linear and quadratic approaches, the results obtained are very similar. These DR approaches are the most involved and thus more support the fixed costs of the distribution network. Due to the very specific characteristics of the DR elastic approach, based on elasticity price demand, in this scenario has no scheduling for using DR programs, hence, are not allocated any costs.

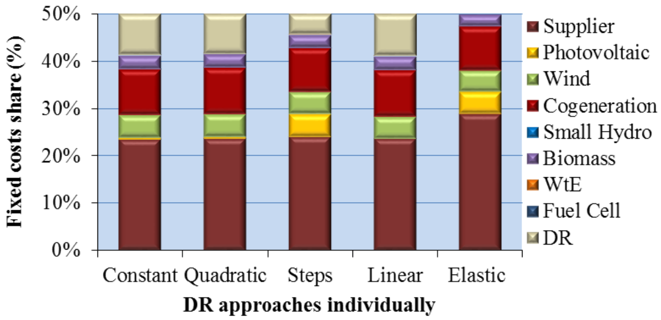


Figure 4. Fixed costs allocation by generation and DR resources.

In regard to the costs incurred by consumption of resources, the Fig.5 allows identify which consumers that more pay the fixed costs of network, which are proportional to the consumption they require the distribution network.

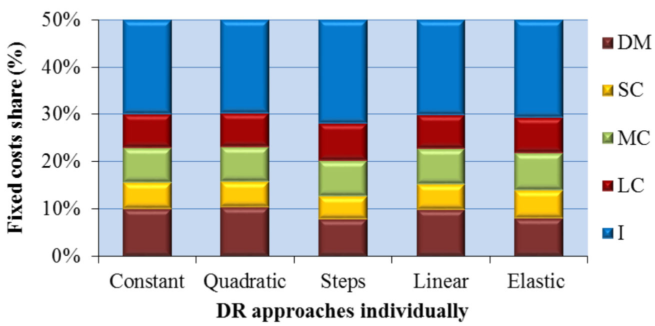


Figure 5. Fixed costs allocation by consumer type.

Fig.6 illustrates in detail the fixed costs that are allocated to generation resources, when the DR approaches are implemented individually, in each branch of the distribution network. As can be seen in Fig.6, the external suppliers have a more significant contribution to the closest bus where its energy is injected, which is on the bus 1. In the branches that make up the distribution network that are furthest from the bus 1, the DG and DR resources have a higher impact on network usage, and as such, supports more costs in the most distant branches of the bus 1.

For scenario a), on average the DG resources are responsible for paying 17.84%, the external suppliers by 23.62% and DR constant approach allocates 8.54% of the total fixed costs attributed to the generation resources, which in turn are 50% of total fixed cost of distribution network.

In the scenario b), DG allocate resources 18.03% of the fixed costs, while support external suppliers is 23.67% and DR quadratic approach accounts for 8.30%.

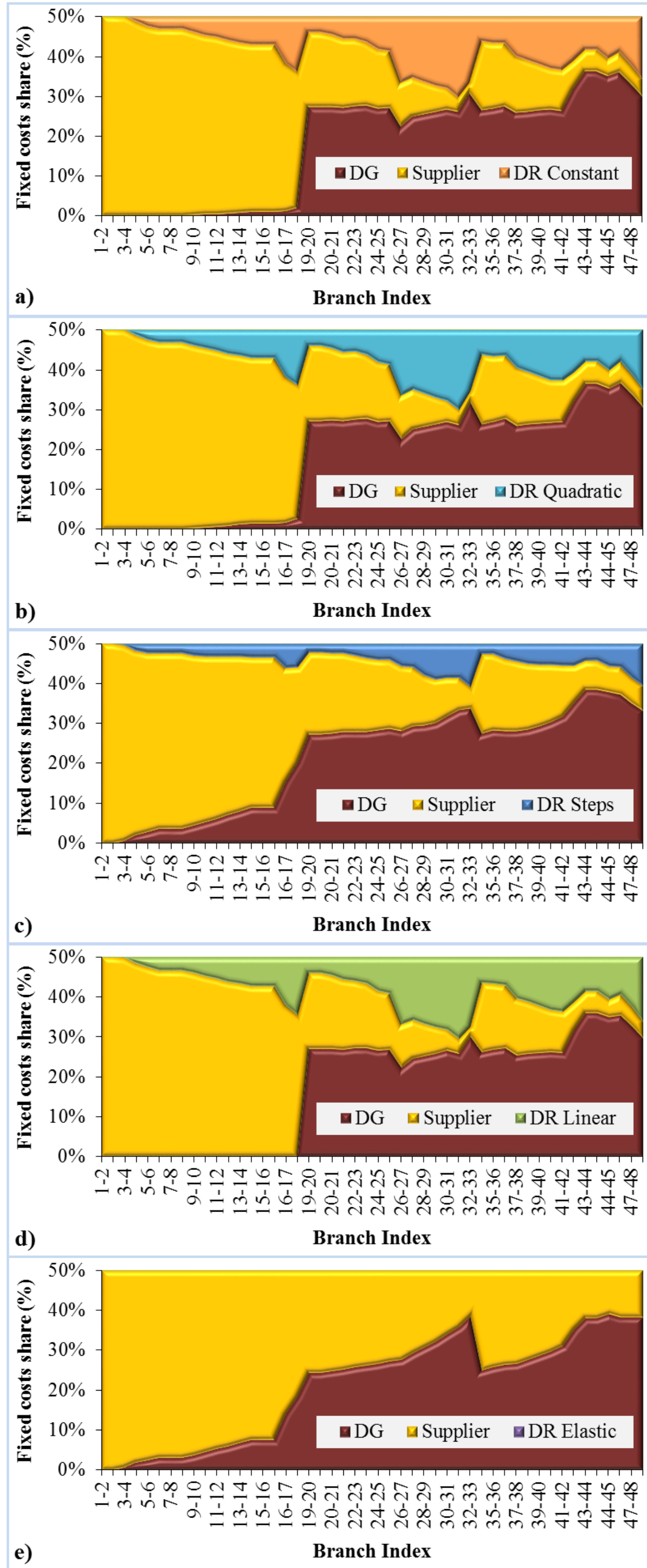


Figure 6. Fixed costs allocation by generation with DR approaches.

The results which contains the scenario of implementation of the DR steps approach is represented in c), which on average, DG resources account for 21.60%, the external suppliers by 24.09% and DR steps approach 4.31%, to allocate fixed costs.

The scenario d) shows the allocation of fixed costs on each branch, when considering the implementation of DR linear approach. Therefore, on average, the DG resources allocates 17.50%, the external suppliers 23.71% and DR linear approach to about 8.79% of the fixed costs.

Finally, the scenario e) results from the implementation of the DR elastic approach, as previously explained, due to their peculiar characteristics of this approach, this didn't has participation, being the costs divided by the DG resources with 21.06% and external suppliers with 28.94%, for the generation resources.

### *B. Fixed costs allocation with DR approaches simultaneous*

Fig. 7 shows the results of fixed cost allocation in each branch, for the generation resources, when five distinct DR approaches are implemented simultaneously. The scenario a) identifies the fixed costs allocation for the three sets of generation resource (DG, external suppliers and DR programs), while the scenario b) shows in detail the contribution of each of the DR approaches implemented, for all branches of the network distribution.

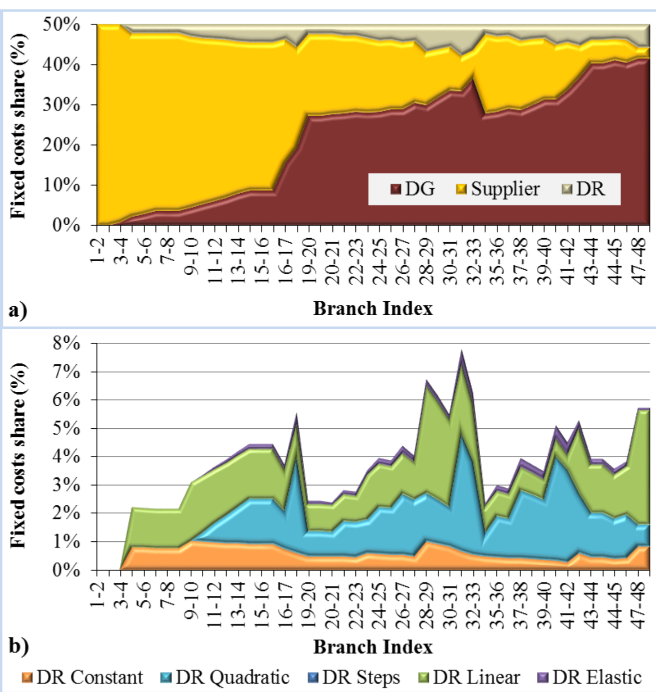


Figure 7. Fixed costs allocation: a) all generation resources; and b) five distinct DR approaches.

In the scenario b) it is possible to verify that DR approaches that more allocate fixed costs are the approaches of DR constant, quadratic and linear, such as in scenarios where the approaches are implemented individually.

The Fig. 8, Fig. 9 and Fig. 10 illustrate a particular situation, which corresponds to the contributions of each resource in the branch 19-34.

Fig. 8 presents the contributions of consumption resource, by consumer type. As can be seen in Fig. 8, the consumers more impact causes in the branch 19-34 are consumers of Large Commerce (LC) and Industrial (I) type. Also these consumers allocate most of the fixed costs for the branch 19-34.

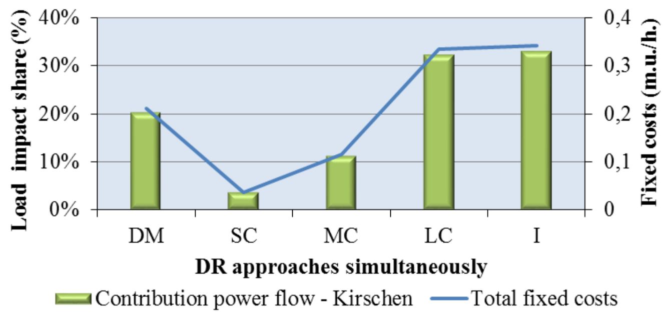


Figure 8. Contribution of consumers' type (loads) for branch 19-34.

In Fig. 9 presents the contributions of generation resources, determined by Kirschen's tracing method, as well as the fixed costs allocated to each resource type. The DG resources have an impact of 54.54%, while the external suppliers is 40.55%, and DR approaches implemented simultaneously of 4.91%, allocated for the five types of DR approaches implemented.

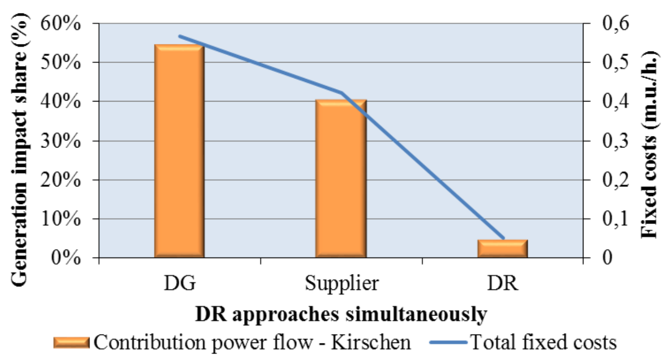


Figure 9. Contribution of generation resources for branch 19-34.

Fig. 10 allows to check in detail the contribution of each type of DR approach in the branch 19-34 of the distribution network. Thus, it appears that the DR approaches major contribution to the branch 19-34 are the DR linear, quadratic and constant approaches. Furthermore, the DR steps approach has no contribution.

Note that when DR approaches are applied simultaneously, each consumer can only associate to two types of approaches. Moreover, the DR approaches includes innovative and complex constraints, such as the amount of maximum and minimum use that can participate, as explained in sub-section II-A.

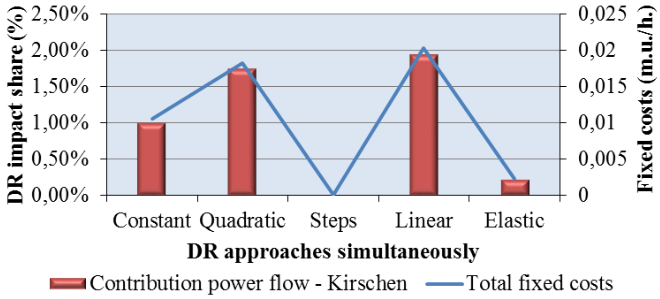


Figure 10. Contribution of DR approaches for branch 19-34.

## V. Conclusions

The proposed methodology allows solving the problem of fixed costs allocation of a distribution network, with large numbers of distributed energy resources, in particular with high presence of DG resources. For determining the fixed costs of the distribution network, using Kirschen's tracing method for determining the impact of the resources in the distribution network, and a variant of the MW-mile method for allocation of fixed costs.

The developed scenarios focus on the study of the implementation of several DR approaches, as well as the impact that each DR approach can have on the allocation of fixed costs of a distribution network.

DR approaches are implemented in two different ways, individually and simultaneously. Through these two ways of implementation it can be seen that both individually and simultaneously, the DR approaches whose consumers have larger participation are the DR constant, quadratic and linear approaches. However, it appears that when the DR approaches are implemented individually there is a more participation in DR events of consumers than when the DR approaches are implemented simultaneously.

In what concerns to the impact that the DG resources have in the distribution network, it can be seen that the presence of several DG technologies distributed by the network allows to reduce the power flow, essentially in the nearest branches of the connection point with external suppliers.

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