Dynamic Optimization of Low Voltage Distribution Networks, in a Strong Embedded Microgeneration Context and Strong Electric Vehicle Penetration

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Abstract—In order to respond to the growing search for new clean energy sources and to an imperative and global interest on the reduction of CO₂ emissions, arises an inevitable solution, the electric vehicle and the decentralized micro production units. Both of these have direct impact on the power grid network, where the dynamic between offer/demand must be predicted and balanced.

This dissertation addresses the issue by conducting a study of consumption tariffs that attract the electric vehicle charging to periods of time with lower network utility and major photovoltaic (PV) production. This article starts with a contextualization of the subject, followed by the development of strategies created with the intent of controlling Plug-in Electric Vehicle’s (PEV) load connections, through tariffs. Finally, a set of case studies have been completed in order to simulate and compare the PEV’s penetration and PV production effect on a real grid model.

The results support the optimization strategy suggested, through a significant reduction of current and voltage perturbations and the system losses, resulting in an optimal networks exploration involving electric vehicles and decentralized micro producers.

Keywords - Low voltage network's exploration, optimization, electric vehicle, photovoltaic microgeneration, consumption tariffs.

I. INTRODUCTION

NOWADAYS it’s impossible to separate the using of electric energy from our quotidian lives. The energy sector assumes a fundamental part of every government's vision. Electricity can’t be stored and has to be consumed on the first 1/10 of a second after its production. This implies that in every moment during the day, the available energy flowing in the grid should be equal to the demand. Taking into account the presented characteristics and the fact that the loads network diagram varies during the day, it’s verified that some of the installed power is underused during the lower demand periods. This happens because the installed power is projected to satisfy the consumption peak period. The increasing number of renewable microgeneration units and electric vehicles load’s connected to the grid amplifies the described problem, making the system capability more and more underexploited [4].

Plug-in electric vehicles (PEVs) are growing in popularity as more efficient low emission alternatives to the conventional fuel-based automobiles. Depleting natural oil and fossil fuel reserves, rising petrol costs, and increasing governmental regulations to adopt more sustainable technologies have driven the development of plug-in electric vehicles. Nissan, Mitsubishi, General Motors, and Chevrolet [1]–[3] have already begun to roll out PEVs from their production lines with many more automotive companies promising to rapidly expand into the PEV market.

On one hand the Plug-in Electric Vehicle (PEV) charging tends to increase the demand during the peak period (period when PEV users arrive at home after work), and on the other hand, Photovoltaics (PV) production peak overlap with periods of lower energy demand from the grid. An important component of electric mobility consists on the electric vehicle integration form on the grid. Considering the networks evolution, through the concept of smart grids, the PEVs integration turns to be more and more complex, but also allows to reduce the negative impact on the grid, like overloads and disrespect of electric quality limits [5].

Without any optimal exploitation form, the connection of a significant number of PEVs to existing networks could bring several problems to the good function of the system. Using load control strategies, it’s possible to attract the PEV’s charging to periods with more energy available on the grid. This approach can solve the problem without need to restructure the system.

In a PEV's penetration paradigm, charging management allows the reduction of load’s peaks through accommodating PEVs charge on high renewable production periods, improving the energy consumption diagram equilibrium. Smart grids are becoming more and more active and efficient, following a path where electric grids are less and less passive [6]. This paper proposes to study the exploitation forms of LV electric grids in the future, in random environments of high load’s variability resulting from PEV’s quick and slow charging and a growing PV production.

The main objective is to identify optimal solutions for the network exploitation in these scenarios, improving system losses, reducing voltage and current’s perturbations and trying to dynamically predict consumer behaviour in order to balance the system.

II. PROBLEM IDENTIFICATION AND PROPOSED SOLUTION

The electric grid is projected with a defined capacity, according with the load maximum value expected during the day. The bigger the load peak, the bigger the grid’s capacity. An unpredicted load connection, can result in an overload and, consequently, in the need of an installed capacity restructuring. Increasing the grid capacity costs time and money, so, the grid’s explorer company has interest in optimizing the loads connection to the existing grid, avoiding a new investment to restructure the network.
The proposed optimal solution consist in a strategy that “redirects” the non-predicted loads (PEV) to minor energy demand periods. This solution will avoid the grid overload and, on the other hand, will monetize the grid capacity during all day.

**Problem:** how can it be achieved?

**Solution:** Through attractive consumption tariffs, exclusives to electric vehicles charging process.

The random and non-optimized connection of Plug-in Electric Vehicle’s to the grid causes system problems like power loss, overload and voltage fluctuation. Electric vehicles’ batteries represents significant weighty loads to take in account on the grid exploitation strategy. On the other hand, PV micro-generation results on a rising energy flow in the grid during high solar incidence periods, leading to an energy excess without demand. The PV micro-generation happens only during the day and, typically, the generation peak does not overlap with the consumption peak, as it’s shown in Figure 1 and 2.

Based on these facts, it’s obvious that electric distribution companies are interested in avoiding the increase of energy demand during consumption peaks periods and, on the other hand, are interested in incentivizing that same increase during low demand periods, when the grid’s capacity is underused.

Analysing the daily residential load curve (Figure 2), based in a model developed from a distribution transformer data [7], it’s clear that the load peak is registered between 17h00 and 18h00. It’s important to point out the existence of two minor periods of grid utilization: the first one between 24h00 and 08h00 and the second one between 10h00 and 15h00.

Relatively to PV micro-generation, the generation peak is registered between 12h00 and 14h00, as it’s presented by the typical production curve for a PV residential panel in Figure 1 (courtesy of EDP Distribuição).

Taking into account these conditions, the proposed optimization strategy consists in captivating PEV’s charging to periods with lower grid’s utilization, avoiding an increase in the consumption during load peaks hours.

The proposed optimization for electric grid exploitations is based on daily consumption tariffs. This electric tariffs should be attractive and exclusives for PEV’s charging. Electric distribution companies should offer this exclusives PEV tariffs with a competitive price, lower than the ones practiced for normal consumption tariffs. This price difference will instigate energy consumption during these time periods of the day.

**Problem:** how can it be achieved?

**Solution:** Through attractive consumption tariffs, exclusives to electric vehicles charging process.

Nowadays EDP offers their clients the "energy2move" tariff [8], exclusive to clients that own electric vehicles. This tariff offers 10% discount on the total house consumption during the night. Enforcing the company position in the electric mobility market EDP recently released the system "change2move" [8], which consists on a PEV charging system compatible with several brands’ vehicles. The system permits quick (32A) and slow (16A) charging.

The proposed optimal solution consists on applying the exclusive PEV charging tariffs through the "change2move" system, where only the system’s consumed energy will benefit from the tariff’s attractive prices.

The proposed solution suggests the creation of 4 daily tariffs:

- **RED Tariff (18 h00-22h00)** – For clients with high charging urgency. Indicated for cases in which the user needs to charge his PEV as soon as possible, in order to use it immediately. The kWh’s price for this tariff should be very high, when compared with the other proposed tariffs. It’s proposed that the kWh’s price should be equal to the market price.

- **BLUE Tariff (22h00-01h00)** – For clients with medium charging urgency. Indicated for cases in which the user needs to use the vehicle later, during the same day. Because the energetic tariff is available in a schedule partially off-peak, the kWh’s price should be higher than RED Tariff but lower than GREEN Tariff.

- **GREEN Tariff (01h00-09h00)** - For clients with low charging urgency. Indicated for cases in which the user only needs to use the vehicle again the next day. For this schedule the kWh’s price should be the lowest.

- **SUN Tariff (10h00-17h00)** - Tariff created to encourage PEV charging during user’s work period of the day. Indicated to explore the possibility of charging the vehicle at work and/or at home during lunch time. Commercial vehicles can be connected to the grid during employee’s break time. For this schedule the kWh’s price should be the lowest from all of the proposed tariffs, because there will be more available energy during this period of the day, resulting from PV production.
The electric distribution company interest is to have the majority of PEVs charging during BLUE and GREEN periods.

To allow the charging process of the same vehicle in different places, using the same proposed tariffs (RED, BLUE, GREEN and SUN), is suggested in this article to associate to the "change2move" a billing system or app through client identification. With this hypothesis, users could charge their vehicles at every "change2move" system, through an ID card or a smartphone app, and automatically associate the charging consumed energy to their client’s bill.

The proposed optimization will be applied during the Case Study.

III. MODEL AND SIMULATION

A. Power flow

Power Flow is the steady state solution for an electric energy system, considering, generators, loads and the bus network. Power Flow equations [9] describe the flowing energy in the grid through voltage and current’s relationship for a time interval, represented by complex phasors, for every system node.

These equations are generally presented in the real form, where complex voltage is expressed in polar notation:

\[ V_i = |V_i|\exp (j\theta_i) \quad , \theta_i = \angle V_i \] (1)

and, the reactive and active power are, respectively, presented in the rectangular form:

\[ P_i = P_{G_i} - P_{D_i} = \sum_{k=1}^{n} \left( |V_i||V_k|G_{ik}\cos(\theta_i - \theta_k) + |V_i||V_k|B_{ik}\sin(\theta_i - \theta_k) \right) \] (2)

\[ Q_i = Q_{G_i} - Q_{D_i} = \sum_{k=1}^{n} \left( |V_i||V_k|G_{ik}\sin(\theta_i - \theta_k) - |V_i||V_k|B_{ik}\cos(\theta_i - \theta_k) \right) \]

where, \( G_{ij} \) and \( B_{ij} \) are, respectively, the nodal conductance and susceptance. \( P_{G_i} \) and \( P_{D_i} \) are the generated and consumed active power, respectively, at the same node.

For solving the Power Flow non-linear equations, the generally used technique is the Newton-Raphson method, because it presents a clearly superior convergence velocity, when compared with the Gauss-Seidel method. The Newton-Raphson method lines requires active and reactive power derived (Power Flow equations) in function of module’s and voltage angle (Jacobian):

\[
\begin{bmatrix}
J_{11} & J_{12} \\
J_{21} & J_{22}
\end{bmatrix}
\begin{bmatrix}
\Delta \theta \\
\Delta V
\end{bmatrix} =
\begin{bmatrix}
\Delta P \\
\Delta Q
\end{bmatrix}
\]

(3)

where:

\[ J_{11} = \frac{\partial P_{bus}}{\partial \theta}, \quad J_{12} = \frac{\partial P_{bus}}{\partial V}, \quad J_{21} = \frac{\partial Q_{bus}}{\partial \theta}, \quad J_{22} = \frac{\partial Q_{bus}}{\partial V} \] (4)

B. Power Losses

Considering an \( n \) nodes electric grid, the line transmission losses are defined as:

\[ P_{loss} = R_{k,k+1} \left( |V_{k+1} - V_k| |y_{k,k+1}| \right)^2 \] (5)

where \( V_k \) represents the \( k \) node voltage, \( R_{k,k+1} \) and \( y_{k,k+1} \) represents, respectively, the line section resistance and admittance between \( k \) and \( k+1 \) nodes.

The total system losses is defined by the sum of every grid’s section losses:

\[ P_{totalloss} = \sum_{k=0}^{n-1} P_{loss} = \sum_{k=0}^{n-1} R_{k,k+1} \left( |V_{k+1} - V_k| |y_{k,k+1}| \right)^2 \] (6)

C. System Constraints

For the case study three system’s constraints are considered:

Voltage Constraint

The voltage constraint define a maximum and minimum variation limit for the electric voltage. These limits are based on standard values used by electricity distribution companies. For this case study the defined limits are +5% and -10% (\( V_{\text{min}} = 0.9 \) p.u. and \( V_{\text{max}} = 1.05 \) p.u.).

\[ V_{\text{min}} \leq V_k \leq V_{\text{max}} \quad k = 1, \ldots, n \] (7)

where \( k \) and \( n \) are the node number and the system’s total number of nodes, respectively.

Current Constraint

The current constraint define a maximum and minimum limit for electric current values. These limits are based on standard values used by electricity distribution companies. For this case study the defined limits are \( I_{\text{min}} = 90 \) A and \( I_{\text{max}} = 355 \) A.

\[ I_{\text{min}} \leq I_k \leq I_{\text{max}} \quad k = 1, \ldots, n \] (8)

where \( k \) and \( n \) are the node number and the system’s total number of nodes, respectively.

Demand Constraint

The demand constraint prevents grid overloads. A maximum demand limit is defined, under this level the system operates garantidly without overload resulting problems.

The maximum demand level (\( D_{\text{max}} \)) is defined by the grid’s load maximum value during the day, without considering any PEV an PV penetration. Because of this, the system’s total power consumption (\( P_{total\text{ demand}} \)) should never be higher than the maximum demand level:

\[ P_{total\text{ demand}} = \sum_{k} P_{k,\text{demand}} \leq D_{\Delta t,\text{max}} \] (9)
where, $P_{load}$ represents the power consumption of node $k$ at time interval $\Delta t$.

D. Simulation

In order to effectively experiment several grid exploitation hypothesis DPlan - Distribution Planning program was used [10]. DPlan is an analysis and optimization software for electricity distribution systems that assists the user’s decision making concerning energy system’s operation and emergency planning (data from dplan.net). This software is widely used by electricity distribution companies, like EDP. DPlan is mathematically modelled by similar equations to the ones presented before (power flow, system losses, current and voltage limits).

The software was used to simulate the studied grid’s exploitation strategies. For each simulation it was necessary to introduce the respective input files:

- Simulated electric grid;
- Command file;
- File containing clients load information, for every hour of the day.

Note: Producers are also considered clients. In the case of a consumption and production house, it should be considered two distinct clients for the same node.

For each simulation there were collected from DPlan the following data:

- Grid’s edge voltage variations;
- Transformation Point input current variations;
- Total system losses.

IV. CASE STUDIES

The idealized optimization strategies presented before were simulated based on the real grid’s characteristics data.

Part of the energy distributed system installed in Telheiras neighbourhood, Lisbon, was used as model. It’s considered a 42 node’s grid, with only one house per node, as it’s showed in Figure 3. It’s assumed that network’s loads are balanced and that they have the same initial value. The PEV’s penetration loads and PV’s production loads were randomly distributed by the grid connected clients.

A. PEVs Loads

In order to predict the grid’s load variation, it’s important to understand the PEV’s battery impact on client’s load. With 61,027 sold units globally (54% global share) in 2014, and 170,000 sold units since 2010 [11], the Nissan Leaf is the most used PEV all over the world. Based on this fact, Leaf is the reference PEV model used in this study. The Nissan Leaf has a 24 kWh capacity but only 21.3 kW are used (life time battery issues). According to Nissan’s Technical Specifications (nissan.pt data) the total residential battery charge takes 4 hours, using a 32A current (quick charging) or 8 hours, using a 16A current (slow charging). Assuming a constant charging ratio [4] it’s possible to calculate maximum power required to charge the Leaf vehicle at home. Taking the worst case, the 32A quick charging, the maximum charging power is:

\[
32A \times 230V = 7,36 \text{ kW}.
\]

B. Clients

In the present case study it’s assumed that to every grid’s house will be connected a maximum of one PEV. The studied clients’ majority has a 3.45 kVA contracted power. Given the PEV maximum charging power (present before), clients should increase their contracted power by 7.36 kVA to charge a Leaf vehicle at home. So, the total contracted power should be:

\[
3,45 \text{ kVA} + 7,36 \text{ kVA} = 10,81 \text{ kVA}.
\]

Knowing that the 10.81 kVA value is calculated for the worst case, it’s admissible to define as sufficient [12] a 10.35 kVA power for the grid’s houses. Relatively to micro-production, it’s assumed that every producer client uses a 3.68 kW PV micro-generator, with a daily production based on the Figure 1 curve.

It will be presented the study for three penetration levels of electric vehicles: 19%, 38% and 76%. Each tariff will have a major or minor utilization, depending on the defined kWh price. This means that user’s tendency is to charge their vehicle during GREEN period. BLUE should be the second on the list of most used periods, followed by RED, the less attractive tariff.

For each PEV’s penetration level the PEV’s random distribution between the houses connected to the grid is presented on Figure 4, where the box’s colours indicates the practiced tariff when the charging began.

This distribution is based on the assignment’s distribution used on study [7]. Figure 4 presents 21 from all of the 42 clients connected to the grid. Because PEV’s charging are probabilistically independent events, it’s assumed that the remaining 21 clients follow the same behaviour as the first ones.

It’s expected that when a proposed tariff period “opens” the number of PEV connections to the grid is initially high and it will decrease with time. In the limit case, all PEV would be connected to the grid when the desired tariff (Figure 4) turns available.

In order to add realism to the distribution is suggested the hypothesis that not all users are at home when their desired tariff (Figure 4) turns available. This hypothesis induces a
minor delay to PEV connections for each tariff period (RED, BLUE, GREEN and SUN). This minor delay is described by an exponential probability distribution. The exponential distributions varies with the parameter $\lambda$, for higher $\lambda$ values the distribution will be lower.

A different exponential distribution was used for each tariff period, which randomly describes the hour that each PEV was connected to the grid, according to the desired tariff (Figure 4). Particularly for the Sun tariff were used two different exponential distributions during the same time period. The first one describes the slow charging PEV’s distribution and the second one describes only the quick charging PEV’s distribution.

For each Exponential distribution used in the study was defined a value for $\lambda$ and the distribution starting time (absolute zero). The $\lambda$ and absolute zero values assumed are:

![Figure 3. Designated PEV penetration levels and client’s desired tariffs](image3)

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<th>Nível de Penetração do PEV</th>
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* Bars with no color indicate nodes with no PEVs present.

**GREEN Tariff** → $\lambda = 1.25$  
(absolute zero: 01h00)

**BLUE Tariff** → $\lambda = 1$  
(absolute zero: 22h00)

**RED Tariff** → $\lambda = 1$  
(absolute zero: 18h00)

**SUN Tariff** (quick charging) → $\lambda = 1$  
(absolute zero: 12h00)

**SUN Tariff** (slow charging) → $\lambda = 1$  
(absolute zero: 10h00)

Note that for **GREEN Tariff** is defined a superior parameter ($\lambda$), when comparing with others tariffs. It’s assumed that for that period of the day (01h00-09h00) the majority of the users is already at home, allowing them to start charging their vehicles at the tariff “opening” time. Particularly for the SUN Tariff is considered that the quick charging distribution begins at 12h00, instead of 10h00 (tariff opening time). This difference infers some realism to the case study, representing PEV users that charge his vehicle during their lunch time.

### C. Total Load Curve

To calculate the network total load should be considered the load’s non simultaneity. By applying the rules for LV clients connection from *EDP Distribuição* [12] was defined a simultaneity factor of 0.36 for the distribution network loads studied, with exception for PEV charging and PV production loads.

$$\text{PV production loads are characterized by a simultaneity factor of 1, because the solar incidence is assumed to be the same on every house connected to the grid, resulting from the small distance between them. The simultaneity factor defined for PEV charging loads is unitary, because it’s expected that PEVs tend to connect to the grid at same periods of the day, after implementing strategies presented before.}$$

The network daily load variation developed (Figure 4) is based on the one used on [7]. For the case study 42 houses are considered with a contracted power of 10.35 kVA, for each one. To calculate the network load peak for this case, we have:

$$\text{Total Load Peak} = FS \times \sum_{i=1}^{N} P_i$$

where, $N$ represents the number of clients connected to the grid, and $P_i$ represents the contracted power by the client $i$. FS represents the grid simultaneity factor.

**Figures 4 to 6** present the daily load curves, total system losses, and the output Transformation Post current and network edge voltage, respectively.
D. Tests Results

In this section are presented the tests results for cases studied. For each case where tested PEV and/or PV penetration levels of 19%, 38% and 76%. The load’s profile are different from case to case, depending on the optimization strategy and on the PV and PEV penetrations. In order to summarize the high number of simulation tests, there are only presented the most significant results for each case.

CASE A – Photovoltaic Production Effect

In this case is studied the photovoltaic production’s impact on the grid. Three different levels of panel’s penetration were simulated.

Figure 7. 19% PV production effect on system’s load curve. No PV production (blue curve); Systems PV production impact (green curve); PV production (red curve).

Figure 8. 38% PV production effect on system’s load curve. No PV production (blue curve); Systems PV production impact (green curve); PV production (red curve).

Figure 9. 76% PV production effect on system’s load curve. No PV production (blue curve); Systems PV production impact (green curve); PV production (red curve).

There are only presented the most significant perturbation (76% PV production) of the system’s current and voltage at Figure 10. For the others PV penetration levels the perturbations were not sufficiently significant to perturb the system’s good function.

CASE B – Non-Optimized PEV’s Charging Effect

In this case is studied the PEV’s non-optimize charging impact on the grid, without any PV production. The worst case scenario is hypothesised and simulated, with the simultaneously home arrive of all PEV users, putting their vehicles charging. Two situation are presented: the PEV’s slow charging situation with all the vehicles charging between 16h00-24h00; and the PEV’s quick charging situation with all the vehicles charging between 17h00-20h00.

Figure 10. System’s current (left) and voltage (right) variation, with 76% of PV penetration. The red zone indicates negative values of current.

Figure 11. PV production effect on system’s losses.

Figure 12. PEV’s optimized (slow charging between 16h00-24h00) penetration effect on system’s load curve.
Figures 12 and 13 show the grid’s load effects for each charging type. Figure 14 and 15 present the voltage and current variation with 76% of PEV’s penetrations level and the Figures 16 and 17 show the system’s losses.

**CASE C – Optimized PVE’s (25% quick and 75% slow) Charging Effect**

In this case is studied the PEV’s optimized charging impact on the grid, without any PV production. For each PEV penetration level the loads control strategy was used through tariffs (GREEN, BLUE and RED) application. SUN Tariff was not tested because it only make sense to use it when PV production exists.

Figures 18 and Figure 19 shows the grid’s load effect and system’s losses, respectively, for the proposed optimal grid exploitation.

**CASE D – Environment with PV Production and PVE’s Penetrations Effect**

In this case is studied the PEV’s optimized charging impact on the grid, with different levels of PV production. For each PEV penetration level the loads control strategy was used through tariffs (GREEN, BLUE, RED and SUN) application. Only the 19% and 76% of PV panel’s penetration results are presented in order to focus the analysis on the short and long term results.
V. DISCUSSION

- Case A: analysing the case with only PV production it’s clear that during solar incidence peak the energy required from electric grid drops, that’s due to the auto consume. For the photovoltaics’ penetration level of 76% the quantity of produced energy is superior to the demand, creating a negative current at the PT.

- Case B and C: For the PEV’s penetration impact the application of the propose optimization strategy makes a significantly difference. In Case B, the power demand show a significant increases during the peak hours (Figure 12 and 13). Using the proposed tariffs, PEV charging is oriented to the minor consumption hours successfully.
Instead of one consume peak period, there are now two, with a load peak superior to the maximum demand limit only for high PEV penetration levels. The system’s power losses drop for one third of the non-optimal value. There are a period of minor consume during the day that motivates the idealization of SUN tariff.

- Case D: The proposed strategy used in Case C is modified with the addition of another consumption tariff (SUN tariff) during solar incidence peak. For the most exigent case study grid environment is tested with PV penetration and PEV penetration, simultaneously. Analysing these tests is verified the utilization of minor consumption periods during the night for the PEV’s charge (same improvement as in Case C) and also the major PV production period of the day. The use of the excessive quantities of energy on the grid to charge electric vehicles brings important improvements to the quality of the grid exploitation, through the reducing of power system losses and current perturbations.

- The real grid model used in the study tolerated the increase of the number of loads connected to the grid. The PEV’s quick charging simulation, on Case B, was the most problematic test, due to the high value of loads connected during the same time period. It was the only case that the system current limit was not respected. Despite the fact that for this particular case the grid have a sufficient capacity for most of the PEVs impact, the majority of electric grids in function all over the world may not be prepared for these effects [13].

VI. CONCLUSIONS

It is possible to draw some interesting conclusions from the results. The best strategies for electric grid exploitation are based on customer Demand Supply Management (DSM) policies [6] [7], where is delegate to the client his own consumption’s management. Through smartmetering clients can analyses their consumption profile at every moment of the day, allowing them to adapt their energy’s demand to periods with lower price tariffs. The proposed solution is based on a customer DSM policies ideology, using (successfully) the tariff price to orientate the electric vehicles charge to periods with more energy available on the electric system. Exclusive tariffs for PEVs charging accomplish the proposal goal to accommodate vehicle’s charging load during periods of minor consumption and/or major photovoltaic production. This results on a direct regulation of voltage and current magnitudes at all nodes, controlling system peak demand while significantly improving the efficiency and economy of the grid. The benefits out coming from this strategy are demonstrated through the simulation results on a real model grid. Grid’s demand control through consumption tariffs is shown to be beneficial in reducing overall system overloads and power peaks resulting in energy savings and cost reduction through the deferment of costly upgrades and building of new generation plants. Comparing the results it’s clear a loads control strategy is vital for smart grids reinforcement by improving the reliability and security of the supply to the customer.

REFERENCES


