Energy Policy 110 (2017) 105–116

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

# Myths and facts of the utility death spiral

Monica Castaneda[a,b], Maritza Jimenez[a,c], Sebastian Zapata[a,b], Carlos J. Franco[a], Isaac Dyner[a,b,*]

[a] *Universidad Nacional de Colombia, Colombia*
[b] *Universidad Jorge Tadeo Lozano, Colombia*
[c] *Universidad Pontificia Bolivariana, Colombia*

ARTICLE INFO

*Keywords:*
Utility death spiral
Distributed generation
Solar PV
Simulation

ABSTRACT

As the electricity industry is changing worldwide, the swift expansion of basic forms of Distributed Generation (DG), particularly photovoltaic deployment, threatens the current utility business models that during the transitional stages may challenge the reliability of electricity systems and societal welfare. These findings are matters of major concern to policy makers as the shift towards more decentralized power systems must be sustainable, and although this brings great opportunities, it also pauses important challenges. The transition calls for policy and regulation attention. For some researchers, DG development should be accompanied with design changes to distribution tariffs, the addition of connection charge and modifications to Net Metering, while for others, certain of these measures could discourage DG investments. In this context and given multiple uncertainties, the authors propose a system dynamics model to examine the effect of the diffusion of Photovoltaic technology on the revenues of utilities and customers. The paper concludes that for the Colombian case, it is possible under certain conditions to attain a balance between social welfare and the aversion of the utility death spiral through systemic interventions.

## 1. Introduction

With the current diffusion of renewables in power systems, energy policy seeks to balance three conflicting targets: system reliability, environmental quality and consumer affordability. Although none of these have been disregarded, in the industrialized world, the one that has received most attention is $CO_2$ emissions in electricity productions, as Green House Gases (GHGs) affect human life on earth (Boston, 2013; Eyraud et al., 2013; World Energy Council, 2013).

In power systems, largely the greatest emitter of all sectors (OECD/IEA, 2016), decarbonisation can be attained through technology conversion from fossil - towards renewables-based generation. This will in turn have an effect on a number of variables, particularly on reductions in both spot prices and sales of incumbent utilities, as renewables displace more expensive technologies from the merit-order dispatch of energy (Cludius et al., 2013; O'Mahoney and Denny, 2011), prompting declines in revenues and profits of the incumbent utilities (Costello and Hemphill, 2014; Bronski et al., 2014; EPRI, 2014; Satchwell et al., 2015a).

In this context, the *death spiral of utilities* may occur (Castaneda et al., 2017), as the greater ratio between the electricity tariff and the cost of solar PV sparks the adoption of solar PV panels by households. Note that the transportation cost of electricity from the grid – transmission and distribution – is largely fixed and is recovered through charges allocated to customers; these are volumetric, i.e., they can be calculated as the fixed cost divided by the electricity demand (Hledik, 2014). With more PV systems in place, electricity demand falls, which forces utilities to raise charges in order to compensate for energy usage reduction and to help recover costs; the rise in retail rate accelerates PV adoption and further charge increases, inducing a utility death spiral as described in Fig. 1 by reinforcing loops R2 and R3. This, combined with the learning-curve effects, leads to a higher ratio between the electricity tariff and the cost of solar PV, incentivizing PV adoption (see reinforcing loop R1 in Fig. 1).

Although theoretically feasible, others argue that the utility death spiral is unlikely as this implies an unreasonable inertia from utilities and regulators (Eid et al., 2014; Costello and Hemphill, 2014); nonetheless, it is a threat to the incumbent distribution utility and to societal welfare (Clift, 2007; Hirschberg et al., 2004). The move towards a decentralized power industry requires appropriate transitional attention, considering technical, economic and institutional implications (EC, 2015; IEA, 2016).

Given the current energy transformation that is taking place worldwide, this paper explores policy changes that could lead to a more

* Correspondence to: Carrera 80 No. 65–223, Bloque M8A, Medellín, Colombia.
*E-mail addresses:* mcastanr@unal.edu.co (M. Castaneda), mjimenezz@unal.edu.co (M. Jimenez), szapatar@unal.edu.co (S. Zapata), cjfranco@unal.edu.co (C.J. Franco), idyner@unal.edu.co (I. Dyner).

http://dx.doi.org/10.1016/j.enpol.2017.07.063
Received 28 March 2017; Received in revised form 24 June 2017; Accepted 31 July 2017
0301-4215/

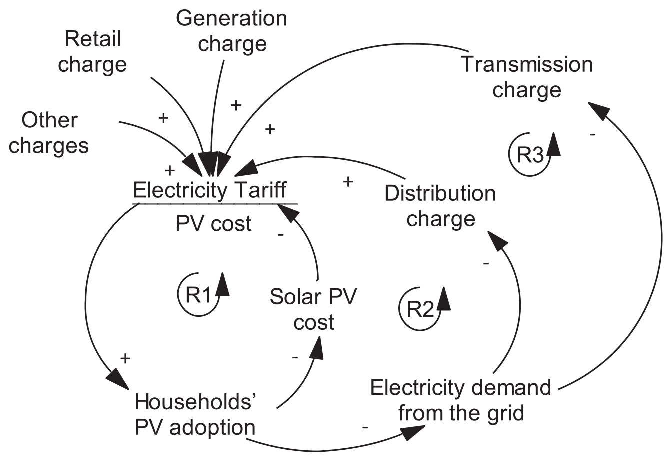


**Fig. 1.** Systems thinking consideration of the utility death spiral. Source: Own elaboration.

sustainable energy paradigm, considering the economic implications on utilities and customers. This paper does not advocate the protection of traditional utility business model; on the contrary, it studies feasible alternatives for a sustainable transition by reducing the negative effects for society, considering the two main stakeholders, customers and suppliers.

Given the multiplicity of possible solutions to the negative effects brought by the abrupt collapse of utilities, the main objective of this research is to identify some of the determinants of a utility death spiral, and some of the likely policy alternatives to confront the transition process under a systemic and sustainable perspective. This paper therefore explicitly addresses some important research questions regarding the death spiral issue, including the following: What are the market conditions that may lead to a death spiral for utilities? What can the regulator and utilities do to avert a death spiral achieving social welfare? Can simulation be of any help to support corrective actions that benefit the technology transition?

To answer the above questions this paper presents a system dynamics (SD) model to assess the financial impact of solar PV development on utilities and customers. The case study is the Colombian electricity market, due partly to its great potential in solar PV energy resources, and mostly because of its commitments to reduce 20% of greenhouse gases emissions by 2030 (Ministerio de Medio Ambiente, 2015).

This research chooses the SD approach over other methodologies, given the nonlinearities and predictive complexities involved. SD is particularly suitable for capturing the dynamics of markets and feedbacks e.g. solar PV cost, transmission and distribution charges. Given the difficulty of predicting solar PV penetration, this approach offers an attractive way of understanding how markets might evolve, for instance by generating insights into how solar PV penetration may affect utilities (Dyner and Larsen, 2001; Ponzo et al., 2011).

The paper is organized as follows. **Section 2** provides an overview of the literature on the penetration of distributed generation (DG), with emphasis on the death spiral problem, the focus of this paper. **Section 3** describes an SD model that has been built to study the dynamics of the current electricity market in Colombia. **Section 4** discusses the simulation results and policy analysis, and finally, the study's conclusions are presented in **Section 5**.

## 2. Utility death spiral issue

The increasing diffusion of distributed solar generation has inspired a broad spectrum of research of its effect on power markets and energy policy. This section aims at addressing the research questions posed earlier by reviewing the existing literature. Thus, studies were categorized according to following issues: the market conditions that may lead to a death spiral for utilities; the policies that may avert the negative impacts of a high penetration of DG or death spiral–if it were possible; and finally, the modelling approaches that have been used to assess the extent of these impacts.

### 2.1. Market conditions to a death spiral

The market conditions that may lead to the utility death spiral were identified by Costello and Hemphill (2014), who present a quantitative analysis of the necessary economic and regulatory conditions for the utility death spiral; although possible, the paper argues that it is unlikely as it would assume an inert attitude from utilities and regulators.

Others have studied the effects of distributed solar generation on both customers and utilities under different market conditions. For example, Darghouth et al. (2011) estimated the bill savings obtained by residential and commercial PV customers under different compensation mechanisms for distributed PV and tariff designs; they found that Net Metering regulation (which offsets households' electricity consumption from the grid during the evenings against their electricity surpluses during the day, yielding the net energy consumed or dispatched (Comello and Reichelstein, 2017; Geffert and Strunk, 2017) provides significantly greater bill savings in comparison with other compensation mechanisms. Oliva et al. (2016) study the short-term financial impacts of the penetration of PV systems on the different agents involved in the electricity sector of New South Wales, Australia. For this, they considered different compensation mechanisms: gross and net PV feed-in tariffs; and different retail tariff arrangements: block and time-of-use retail electricity tariffs. Their findings suggest that the current compensation mechanism, i.e., net PV feed-in tariff, grants moderate revenues to PV adopters, incentivising self-consumption, while causing revenue losses for network service providers and threatening the retail business. Additionally, time-of-use rates may exacerbate these effects on revenue due to the match between shoulder and peak tariff rates with hours of solar output.

Another effect of distributed solar generation on customers is the cross-subsidisation of grid costs between PV adopters and no-adopters (Eid et al., 2014). For instance, Eid et al. (2014) studied the effects of different types of Net Metering methods and tariff designs on Distribution System Operator (DSO) incomes, policy objectives and cross subsidies between network users in Spain. The main conclusion from the study is that Net Metering along with a volumetric charge produce a DSO income-reduction and cross-subsidies; this effect is enlarged with a larger period for which surplus of electricity production is valid.

Finally, Satchwell et al. (2015a) analysed the financial impact of solar PV on utility shareholders and ratepayers. They found that distributed solar generation may reduce the revenue of utilities; however, the electricity tariffs would increase moderately even at the highest levels of PV penetration.

### 2.2. Policies to avert negative effects of high solar DG penetration

Although Satchwell et al. (2015a) dismiss the possibility of a death spiral, they recognized the revenue erosion of utilities caused by solar DG penetration. In a later study, Satchwell et al. (2015b) use a financial model to quantify the efficacy of different policies for mitigating the financial impacts of solar DG on utilities. Some of these policies have been applied to offset the revenue erosion caused by energy efficiency programs. However, they indicate that these may contribute to the adoption of solar-plus-battery systems, exacerbating the financial problem of utilities.

Other authors that propose changes in tariff designs to avoid cross-subsidisation are Picciariello et al. (2015a), who quantify cross-subsidies from consumers to prosumers by comparing the tariffs of network users and the costs they imposed on the system; these costs are estimated through a Reference Network Model (RNM). They use a