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Optimal Power Flow analysis for active power dispatch load dependent voltage Considering models

Análisis de flujo de potencia óptimo para el voltaje activo dependiente de la carga de despacho considerando los modelos

GARCÍA-GUZMÁN, José Miguel*†, TORRES-JIMÉNEZ, Jacinto and GONZÁLEZ-PONCE, María del Refugio

Instituto Tecnológico Superior de Irapuato, Carretera Irapuato-Silao km 12.5, Col. El Copal, C. P. 36821, Irapuato, Gto

ID 1st Author: *José Miguel, García-Guzmán* / **ORC ID**: 0000-0001-6505-135X, **Researcher ID Thomson**: S-5892-2018, **CVU CONACYT ID:** 470152

ID 1st Coauthor: *Jacinto, Torres-Jiménez*

ID 2nd Coauthor: *María del Refugio, González-Ponce* / **ORC ID:** 0000-0002-1170-2126, **Researcher ID Thomson**: S-4503-2018, **CVU CONACYT ID:** 327208

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Abstract

This work is presented in the Optimal Power Flow (OPF) analysis to determine the active power dispatch of power systems When the voltage dependent load models are Considered in Such analysis. The load models Considered In This work are the exponential and composed models, are integrated into OPF Which formulation using an existent program developed in Matlab programming language. Two study cases With the IEEE power system of five nodes and New England power system are Carried out to determine the optimal active power dispatch and points of steady-state operation of These systems Considering load models. The case studies show That the load models have a significant effect on the FPO results, since the losses and the demand for power, Both active and reactive, decrease the generation cost Causing Also to decrease.

OPF, load model, active power dispatch, generation cost

Resumen

En este trabajo se presenta el análisis del problema de Flujos de Potencia Óptimos (FPO) para llevar a cabo el despacho de potencia activa de sistemas de potencia cuando se consideran los modelos de cargas dependientes de voltaje. Los modelos de carga considerados son el modelo exponencial y el compuesto, los cuales son integrados en la formulación de FPO usando un programa existente desarrollado en Matlab. Dos casos de estudio con el sistema de prueba de 5 nodos del IEEE y el sistema de potencia de Nueva Inglaterra son llevados a cabo para determinar el despacho de potencia activa y los puntos óptimos de operación de estado estacionario de estos sistemas considerando los modelos de carga. Los casos de estudio muestran que los modelos de carga tienen un efecto considerable en los resultados de FPO, ya que las pérdidas y la demanda de potencia, tanto activa como reactiva, disminuyen haciendo que el costo de generación también presente un decremento en su valor.

FPO, modelos de carga, despacho de potencia activa, costo de generación

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* Correspondence to Author (email: migarcia@itesi.edu.mx)
† Researcher contributing first author.

Introduction

The energy companies must achieve maximum efficiency while minimizing the cost of generation, so that the profitability of the generating units is indispensable. This necessitates the addition of an analysis Optimal Power Flow (FPO), because by this analysis can meet the demand of active power in the most optimal way. In 1962 importance to research FPO (Abdel & Narayana, 2003, Happ, 1977) and a rigorous mathematical approach for analyzing FPO was first proposed by J. Carpentier, who made it as a problem of nonlinear programming occurred (Ahmad, 1991).

Flow analysis Optimal Power (FPO) allows optimizing a subject to various restrictions objective function, thus the optimal state of steady state operation of the power system is determined. The objective functions may consider economic, security or environmental aspects of the electrical system. In this work this function corresponds the sum of cost functions power generation Activa2 (Ahmad, 1991; Ambriz et al, 1998). The restrictions are physical laws governing power generation, transmission capacity power system, the nominal design limits of the electrical equipment and the same operating system (Acha et al, 2004).

Restrictions are equality and inequality, they correspond to the first balance equations active and reactive power at each node of the electrical system, and the latter are those regarding operating system and physical limits. FPO studies have become an essential tool in the planning and operation of power systems. In operation, a FPO can perform actions considering the optimal monitoring system operating restrictions, while planning studies to determine optimal FPO serve scenarios considering the evolution of power systems (Pizano, 2010). FPO studies have become an essential tool in the planning and operation of power systems. In operation, a FPO can perform actions considering the optimal monitoring system operating restrictions, while planning studies to determine optimal FPO serve scenarios considering the evolution of power systems (Pizano, 2010). FPO studies have become an essential tool in the planning and operation of power systems.

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FPO results are influenced by the models used for the main electrical components SEP such as transformers, generators, transmission lines and loads. Modeling latter a strong impact on the value of the objective function and the state variables of the system (El-Hawary & Dias, 1987), however, such modeling is difficult because of the different types of loads connected to the system electrical, environmental conditions and load levels thereof. Therefore, modeling loads in studies of SEPs is done considering various simplifications. Load models are classified into two types: static and dynamic models.

In this paper static models dependent voltage electrical charges to SEP are integrated to obtain the optimal dispatch of generation (DOG) considering such loads models and determine the impact of these charges on behalf of the study results FPO.

Analysis of Optimal Power Flow

In general, the mathematical formulation of the problem of FPO can be raised as a problem of nonlinear constrained optimization, in which the cost of active power generation of each generator is minimized without violating constraints of the system. The FPO problem is formulated as follows (Ambriz, 1998; Ahmad, 1991; Monticelli and Liu, 1992),

$$\begin{aligned} &\text{Minimizar} \quad f(x) \\ &\text{Sujeta a} \quad h(x) = 0 \\ &\qquad\qquad g(x) \le 0 \\ &\qquad \text{y} \quad y^{\min} \le y \le y^{\max} \end{aligned} \tag{1}$$

where y is the vector of state variables of the system, f (y) it is the objective function to optimize, in this case the cost function of active power generation, h (y) represents equality constraints given by equations balance of power and g (y) are the inequality constraints, which consist of the limits of the control and status variables and functional inequality constraints.

Modeling dependent voltage loads

The operation of a power system depends on the ability to match the electrical output of the generator units to the power system load. Consequently, the load characteristics have an important influence on the power flow studies (Kundur et al, 1994). For this reason it is very important to model the loads as close to practice, but this modeling is complicated because a bus typical load is composed of a large number of devices, for that reason the exact composition of the filler is difficult to estimate. In addition, the composition changes depending on many factors, including time (hour, day, season), weather conditions and the state of the economy (Concordia & Ihara, 1982).

Static loads modeling is performed based on the variables that affect the active and reactive power consumed in a given node. These variables are the voltages on buses and mains frequency (Rodriguez et al, 2013). Models dependent voltage loads used in the analysis of power systems are exponential and polynomial type, which are expressed for a node i, respectively, by (3) and (4) as follows (Kundur et al, 1994 ; Price et al, 1988),

$$P_{i,\exp}(V) = P_{i,0}\left(\frac{V_i}{V_{i,0}}\right)^{\alpha} \tag{2}$$

$$P_{i,ZIP}(V) = P_{i,0}\left(a_0 + a_1\left(\frac{V_i}{V_{i,0}}\right) + a_2\left(\frac{V_i}{V_{i,0}}\right)^2\right) \tag{3}$$

where P0, i V0, i represents the power and the rated voltage of node i, Vi is the voltage of node i at a given time, α is the coefficient of the exponential model and (0, 1, 2) represents the model coefficients polynomial, the sum of these coefficients is equal to 1. The polynomial model is also known as ZIP or compound. The same expressions apply for the reactive power, which in this case only the variable P, the exponential coefficient and the model coefficients are denoted ZIP Q, β and b, respectively.

FPO model considering charging models dependent voltage

FPO model used in this paper considers the incorporation of models dependent charge voltage in one unified framework solution.

The resulting pattern of OPF with loads is expressed as,

$$\min \quad C_T(P_{Gi}) = \sum_{i=1}^{Ng} a_i + b_i P_{Gi} + c_i P_{Gi}^2 \tag{4}$$

Sujeto a:

$$\sum_{i=1}^{ng} P_{Gi} - P_{Di} - \sum_{j=1}^{nl} P_{iny,i-j} = 0 \tag{5}$$

$$\sum_{i=1}^{ng} Q_{Gi} - Q_{Di} - \sum_{j=1}^{nl} Q_{iny,i-j} = 0 \tag{6}$$

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \tag{7}$$

$$Q_{Gi}^{\min} \le Q_{Gi} \le Q_{Gi}^{\max} \tag{8}$$

$$V_i^{\min} \le V_i \le V_i^{\max} \tag{9}$$

where

$$P_{Di} = \left\{P_{i,\exp}(V_i), P_{i,ZIP}(V_i)\right\}$$

$$Q_{Di} = \left\{Q_{i,\exp}(V_i), Q_{i,ZIP}(V_i)\right\}$$

Study cases

In this paper a case study is presented with the test system IEEE 5 node (Stagg & El-Abiad, 1968) in which the point of steady state operation of these power systems charging models is determined integrated voltage dependent on the formulation of Optimal Power Flow. This in order to evaluate the effect of such integration load models in the study of active power and at optimum balanced steady state of power systems. For the case studies presented in this paper the coefficients of the exponential model were α = 1.5 for the active power and β = 2.0 for the reactive power (Dias & El-Hawary, 1991), whereas in the case of the polynomial model or ZIP the following values (a0 = 0.55, a1 = 0 is adopted. 15, a2 = 0.35) and (b0 = 0.50, b1 = 0.12, b2 = 0.38) for active and reactive power, respectively. Convergence tolerance considered in the case study was 1x10-9.

The system of 5 nodes IEEE has three nodes load and an additional load connected to a bus generation. Thus, models dependent charge voltage are integrated into these nodes to then calculate optimum operating point of this stationary power system. It should be mentioned that the lower and upper limit generation is 10 and 200 MW, respectively, while the voltage limits are 0.9 ≤ Vi ≤ 1.1 pu. A summary of the results of the equilibrium point with both load models in the FPO shown in Table 1.

Parameter	fixed	Exp.	ZIP
Total cost ($ / hr)	747.97	656.78	700.76
Pdemandada (MW)	165	143.80	152.66
Ppérdidas (MW)	3.05	3.33	3.71
Pgenerada (MW)	168.05	147.14	156.38
Qdemandada (MVar)	40	29.42	35.87
Qpérdidas (MVar)	-25.29	-14.26	-13.30
Qgenerada (MVar)	14.71	15.16	22.57

Table 1 Comparison of results of the test system with 5-node load models

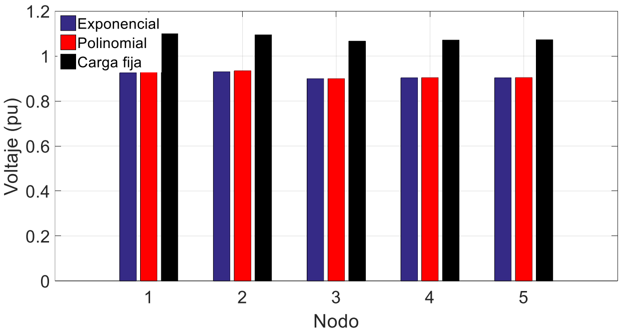

Figure 1 Nodal Voltages considering charging models

Figure 1 shows that the nodal system voltages of 5 nodes decrease when the load models are integrated, which causes decrease flows and reactive power. Furthermore, the results presented in the above table show that the generation cost is lower load models but is important to note that in the case of the exponential model generation cost that is still less. This reduction in cost is due to the decrease in active power generation, Figure 2, which in turn is caused by reduced losses and demand active and reactive power, Figure 3 and 4.

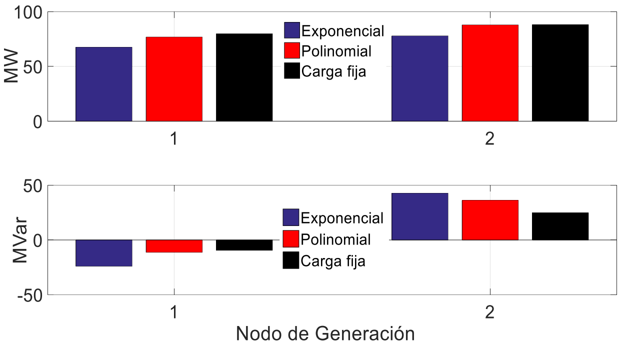

Figure 2 active and reactive power generated considering charging models

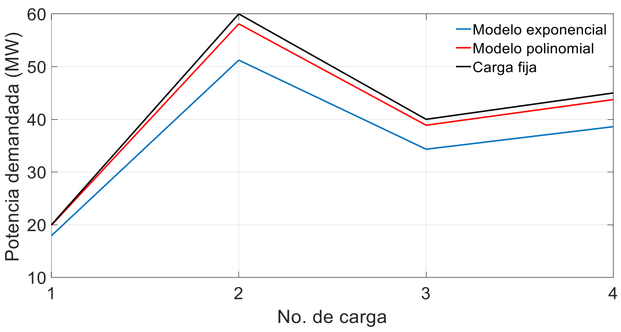

Figure 3 active power demanded considering charging models

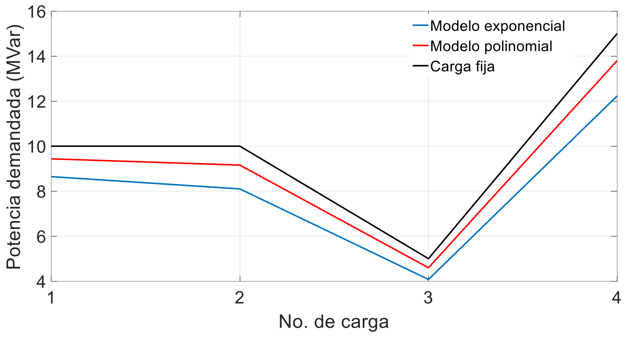

Figure 4 reactive power demanded considering charging models

In this sense, it is easy to infer that modeling the loads has a significant effect on the results of optimal balance point of steady state power system, which for this power system is in particular an operating point of the system cheaper power when loading these models are integrated.

Conclusions

An implementation of the model-dependent charge voltage in the formulation of FPO are presented in order to evaluate the impact of these models in the study of active power and in general the results of the optimum balance point of steady state Power systems.

The results obtained in the case studies showed that integrating models dependent charge voltage the active power losses are decreased and reactive, but also a decrease in power demand also occurs, which makes power generating and thereby decrease the cost of generation. Thus, the generation cost is lower with the two load models, but it should be noted that in the case of exponential model generation cost is even lower.

For the foregoing, it can be concluded that the modeling of the loads has a significant effect on the results of optimal balance point of steady state power system, which for this power system including a point of system operation power cheaper than when loading models are not integrated.

References

Abdel, MA & Narayana, PP (2003). Power Flow Control and Transmission Loss Minimization Model with TCSC for Practical Power Networks. Power Engineering Society General Meeting, 2 (1), 880-884.

Acha, E., Strong, E., Ambriz, PH, & Angeles, C. (2004). FACTS: Modeling and Simultaion in Power Networks. New Jersey: John Wiley & Sons.

Ahmad, A. (1991), PhD Thesis; Optimal Power Flow Solution Using Second Order Newton Method. University of Manchester Institute of Engineering and Electronics.

Ambriz, PH, Acha, E., strong, E, & De la Torre, A. (1998). Incorporation of a UPFC Model in an Optimal Power Flow Method Using Newton's. IEE Proc. Gener., Transm. Distrib., 145 (1), 336-344.

Concordia, C., & Ihara, S. (1982). Load representation in power system stability studies, IEEE Transactions on Power Apparatus and Systems, 969-977.

Dias & El-Hawary. (1991). Effects of Load Modeling in security constrained OPF studies, IEEE Transactions on Power Systems, 6 (1), 87-93.

El-Hawary, ME, & Dias, LG (1987). Incorporation of load models in load-flow studies: effects of model form, IEE Proceedings C-Generation, Transmission and Distribution 134 (1), 27-30.

Happ, HH (1977). Optimal Power Dispatch - A Comprehensive Survey. IEEE Transactions on Power Apparatus and Systems, 841-854.

Kundur, P., Balu, NJ. & Lauby, MG. (1994). Power system stability and control. New York: McGraw-Hill.

Pizano, M., Fort, E., Zamora, C. & Second, R. (2010). Optimal Power Flow Analysis Conventional Using the Matlab Optimization Toolbox. ROPEC International.

Price, WW, Wirgau, KA, Murdoch, A., Mitsche, JV, Vaahedi, E., & El-Kady, M. (1988). Load modeling for power flow and transient stability studies computer, IEEE Transactions on Power Systems, 3 (1), 180-187.

Rodriguez-Garcia, L., Perez-Londono, S., & Mora-Flórez, J. (2013). Parameter estimation of an exponential recovery load model using metaheuristic techniques, 453-461.

Stagg, GW & El-Abiad AH (1968). Computer Methods in Power System Analysis. USA: McGraw-Hill.