Maximizing DGs hosting capacity in active distribution network

Abstract

With the continuous efforts to break out of the traditional grid limitations, more and more interest is pledged into DGs. Increasing the Distributed systems hosting capacity is nowadays one of the main goals to upgrade the grid. This project quantifies the maximum contribution of DGs without causing damage to the grid, in terms of bus voltages, line capacities and many more.

Keywords: Distributed generation, cost function, NLP, hosting capacity

Nomenclature

List of Acronyms

DG Distributed generation.

Cost Maximum hosting capacity.

NLP Nonlinear programming.

OLTC On Load Tap Changing Transformer.

Sets

I Set of nodes.

T Set of OLTC transformers.

F Set of lines.

P Set of periods.

G Set of Generations

Continuous Optimization Variables

GA(i,p) Installed active power capacity of DG unit at a predefined location .

GRSlack(g,i) Reactive power of the substations interconnecting with the upstream grid in period i.

GASlack(g,i) Reactive power of the substations interconnecting with the upstream grid in period i.

GR(i,p) Installed active power capacity of DG unit at a predefined location .

e(i,p) Real component of complex voltage at bus I in period p.

f(i,p) Imaginary component of complex voltage at bus i in period p .

Tappos(p) tap position of transformer in period p.

Parameters

g(i,j) Conductance of the branch linking nodes i and j.

b(i,j) Susceptance of the branch linking nodes i and j.

bsh(i,j) Shunt susceptance of the branch linking nodes i and j.

PL Peak load active power.

QL Peak load reactive power.

Vmin Minimum voltage limit.

Vmax Maximum voltage limit.

Pmax,Pmin, Qmin,Qmax power generation limits

Introduction

The traditional electric grid has many draw-backs.

It meets the basic functionalities: Generation, transmission, and distribution.

However, it is centralized and characterized with passive architecture. It is also relatively inefficient and needs to balance generation and demand.

With the introduction of DGs, which involves the technology of using small-scale power generation technologies located in close proximity to the load being served [2] things have changed. The grid becomes more reliable, flexible and most importantly efficient due to reduced losses through transmission.

With these advantages come challenges like cost of DGs especially renewables, grid interconnection, fault detection and evidently power quality and voltage issues especially to the end user.

The work described in this report provides a solution which significantly increase the amount of DG contribution taking into account constraints set on the nodes voltages, lines capacity using tap changers and power factor to support voltage.

Problem formulation

The optimization problem is formulated relying on rectangular coordinates of complex voltages to avoid additional non-linearities

I. **Objective function:**

The goal of the optimization problem is to maximize the overall amount of DG that can be hosted by the distribution system. The corresponding objective function is called here:

Cost =e= sum(sum(p, -GA(g,p)))

Where cost is the objective function value, noting that we will minimize -GA, which is a continuous variable.

II. Constraints

1- Power flow balance equations:

The active/reactive power balance equations at bus i in each period p are:

ActPwrBalance_fn(i,p).. GA(g,p)+GAslack(g,p) - Pload - line losses =0 similarly for the reactive power equations.

2- Generation limits:

GenLimit_P_L_fn(g,p) Upper Limit on active DG generation (<)

GenLimit_P_G_fn(g,p) Lower Limit on active DG generation (>)

GenLimit_Q_L_fn(g) Upper Limit on reactive DG generation (<)

GenLimit_Q_G_fn(g) Lower Limit on reactive DG generation (>)

Same goes for the slack bus.

3- Line Capacity:

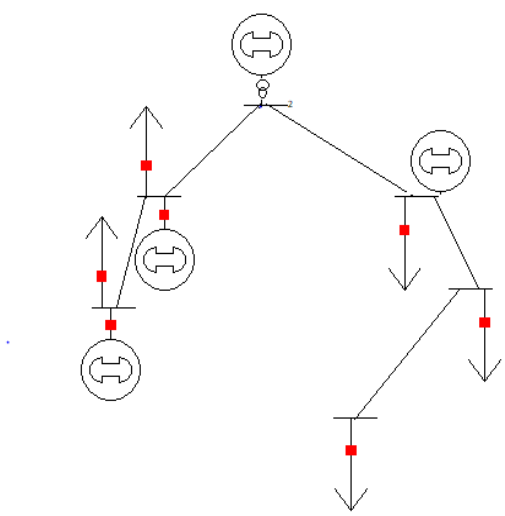
branchlimitfrom(i,p)

branchlimitto(i,p)

This constraint is achieved using a limit on the apparent power going through each line separately.

Case study

1- scenario



In the following case, there are five different buses. There is DG generation at buses 1,2,4; loads at every bus except slack which is connected through a transformer.

For this project, GAMS, General Algebraic Modeling system mainly used to solve optimization and other mathematical problems will be used.

Furthermore, the problem is divided over time periods where there is generation and load variations.

```
Table pldata(p,plchar) Periods_load data

      nbhs     loadp     loadq

000 5.0000    0.4000    0.4000
001 2.0000    0.4000    0.4000
002 68.000    0.5000    0.5000
003 60.000    0.5000    0.5000
004 2.0000    1.0000    1.0000
```

The load varies every period as a percentage of the initial full load.

For the studied case, generation is on three buses as mentioned previously:

```
Table gendata(g,gchar) Generators data

            Bus            P0            Q0

G0            6       1.57145      1.146126
G1            1      1.000000      0.000000
G2            2      1.000000      0.000000
G3            4      1.000000      0.000000
```

With bus 6 being the slack bus, connected to the transformer at bus 0.

2- Results

For the distributed generations:

G1	004	1.26745926546838
G2	000	0.0276932859498861
	001	0.0276932859498861
	002	0.0376597901157759
	003	0.0376597901157759
	004	2
G3	000	2
	001	2

For each period, a different combination of generations is computed keeping the values away from touching the limits of the constraints.

For period 4, the load rises significantly, so a maximum generation at node 2 is spotted.

As for the slack bus:

		Level
G0	000	0.98181204086408
	001	0.98181204086408
	002	1.72663341718181
	003	1.72663341718181
	004	2.28523434212322

It has its own contribution to the system as it is the main feeder.

Similarly, for the taps of the transformer:

		Level
TRFO01	000	16.2572320609905
	001	16.2572320609905
	002	16.3339918078243
	003	16.3339918078243
	004	19.1719921119049

Again, at period 4, there is a rise in load, thus a voltage regulation must be done.

All these numbers are computed keeping the line capacities and nodes voltages within limits:

		Level
000	0	1.02
	1	1.01939523220803
	2	1.01955960336107
	3	1.01805352713653
	4	1.01931447686609
	5	1.01893434711543
	6	1

Voltages are shown in this table for period 0 only.

And finally, the objective cost function holds the maximum contribution of the distributed generation

Discussion and conclusion

This project is modeled as a NLP problem and solved based on that. The values provided are within limit and reasonable.

The result is the maximum contribution of DGs to the grid without exceeding any constraints.

Many features are to be added with new constraints set. The fault analysis can be modeled with a current constraint on the lines.

References

[1] J. Hall, “The new distributed generation,” Telephony Online, Oct. 1, 2001 http://telephonyonline.com/mag/telecom_new_distributed_generation//.

[2] Florin Capitanescu, Luis F. Ochoa, Harag Margossian and Nikos D. Hatziargyriou, TRANSACTIONS ON POWER SYSTEMS, VOL. 30, NO. 1, JANUARY 2015.