Model fidelity and its impact on power grid resource planning under high renewable penetration

by

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Contents

List of Tables

List of Figures

This is the abstract no

Chapter 1

Introduction

Variable Energy Resources (usually refereed as VERs) plays an important role in the energy grid nowadays. It is expected that in 2020, x% of all average consumed power in United States comes from them. One of important characteristics of them is the uncertain behaviour of generation pattern. With the deregulation of the energy market and the decarbonization rules, the grid operators have the challenge to plan efficiently their non-renewable resources (such as oil, coal and gas) in order to keep satisfy grid security and reliability parameters while running the grid at a minimal cost. This work analyses the classical LP version of Economic Dispatch (known as ED) and a MIP instance of Unit Commitment(UC) under different operational constraints and VERs penetration scenarios.

Chapter 2

Literature Review

The first optimal power flow formulation was proposed by ¡put the guy here in 1962¿

Connolly et al. reviews 68 tools to power grid planning with renewable resources, discussing at the end goals, limitations and features of 37 tools [4]. The authors emphasize that, although all the tools are essential to an accurate power planning with renewable resources, there is no perfect tool, and it should be chosen accordingly to project goals, data limitations, horizon and other features.

Yamin discusses different techniques to solve the unit commitment and economic dispatch problems, categorizing them in deterministic, heuristic or stochastic, pointing out the computational challenges and the quality of results for each one of them [23].

Bertsimas et al. proposes a two-stage robust optimization to mitigate demand and variability uncertainties to solve UC when renewable resources are a major key in the field. The authors states the advantages of the method comparing to traditional reserves planning. [1]

Padhy formulates the unit commitment as a general optimization problem and presents a bibliographical survey of the main techniques in the last 30 years, from exhaustive methods such as priority listing, dynamic programming, mixed integer-programming until complex heuristics like fuzzy programming, genetic algorithms and evolutionary programming, emphasizing that these one were not exhaustively tested yet. Models can be classified according to different features, that include:

1. Time frame: decade, year, hour, sub hour
2. Scale: global, national, regional, local
3. Deterministic vs stochastic
4. Optimization vs Simulation
5. Algorithmic vs Heuristic

Cain et al. categorizes the general power flow according to 3 major categories: Power Flow (PF), Economic Dispatch (ED) and Optimal Power Flow (OPF) and describe them based on the assumptions and operational constraints, as shown in table 2.1 [2].

Kassakian et al. discusses the main changes and challenges in the power system for the next years. One of important changes is the increase of VERs, that might have substantially impacts in operating costs, primarily due to the necessity of more reserve generations with different time responses [11]. To mitigate it, 3 suggestions were proposed: improve wind and solar forecast techniques; expand the cooperation and interconnections among regions; reduce decision horizon and resolution levels, to capture a more realistic ramping and reserve effects.

Palmintier and Webster studies the impact of UC models with expansion planning, enhancing that ignoring operating constraints on an expansion planning with VERs could provide higher operating costs and fuel emissions. [17]. Hargreaves et al. proposes a method that combines simulation and stochastic UC to capture precisely the challenges of expanding the capacity with VERs. [9].

Under a scenario where VERs have a considerable penetration in the power system, it is necessary to study their impact. Deane et al. evaluates the UC and ED results at different solving temporal resolutions under one year. The authors discuss that sub-hourly resolutions can deal more accurately with non-thermal inflexibilities, renewable demand variabilities and ramping behaviours than one-hour resolution [5].

One of the alternatives studied in the literature is the use of storage devices to stock energy when the demand is lower than the capacity and use it on an abrupt peak demand, avoiding the use of conventional generators.Safaei and Keith studies different storage technologies and their impact in the emission grid at a 15 minutes time resolution, without transmission constraints and forecast errors. The main insights are that cheap storage does not have major impact in the cost of reducing the carbonization, and seasonal storage are not economically justifiable. [19]. In the other hand, Harris et al. studies the viability of seasonal storage by analysing UC results of different storage scenarios and technologies on a city level, concluding that seasonal storage can bring operational benefits and reduce operating costs and fuel emissions in peak levels.

O'Dwyer and Flynn investigates the effect of storage for ED and stochastic UC plannings under a sub-hourly resolution, concluding that storage can improve system stability and reduce cyclical ramping rates for NVERs, saving operation costs.

Table 2.1: Optimal power flow categories [2]

Category	Name	Constraints					Costs
		Voltage		Transmission	Contingency	Losses	Generator
		Angle	Magnitude				
OPF	ACOPF	x	x	x		x	x
OPF	DCOPF			x	x	x	x
OPF	DOPF	x	x	x		x	
OPF	SCED	x		x	x	x	x
OPF	SCOPF	x	x	x	x	x	x
PF	PF		x			x	x
ED	ED					x	x

Chapter 3

Development

3.1 Data

3.1.1 Reliability Test System Data

To evaluate the proposed models and compare them with the existing literature, it was necessary to use a representative dataset that could be a baseline for the power systems analysis tests. The Institute of Electrical and Electronics Engineers (IEEE) developed a dataset that could allow researchers to compare reliability evaluation techniques, known as IEEE RTS [22].

The first version was developed in 1976 with load data, known as RTS-76, and two other versions were released with data improvements, RTS-86 and RTS-96. Only the RTS-96 has production costs for generating units, a required parameter for the proposed models in this thesis.

The system is divided into 3 areas with 24 buses each, connected by high capacity transmission lines. The topology and the buses relative geographic positions are shown in figure 3.1.

The dataset describes a peak load for each bus. The absolute load in every hour is a percentage the peak load based on 3 components: the week year, the day of week an the hour of the day. The hourly peak changes according to the season and if it is in a weekend or not. For example, the peak load of bus 101 is 108MW. On

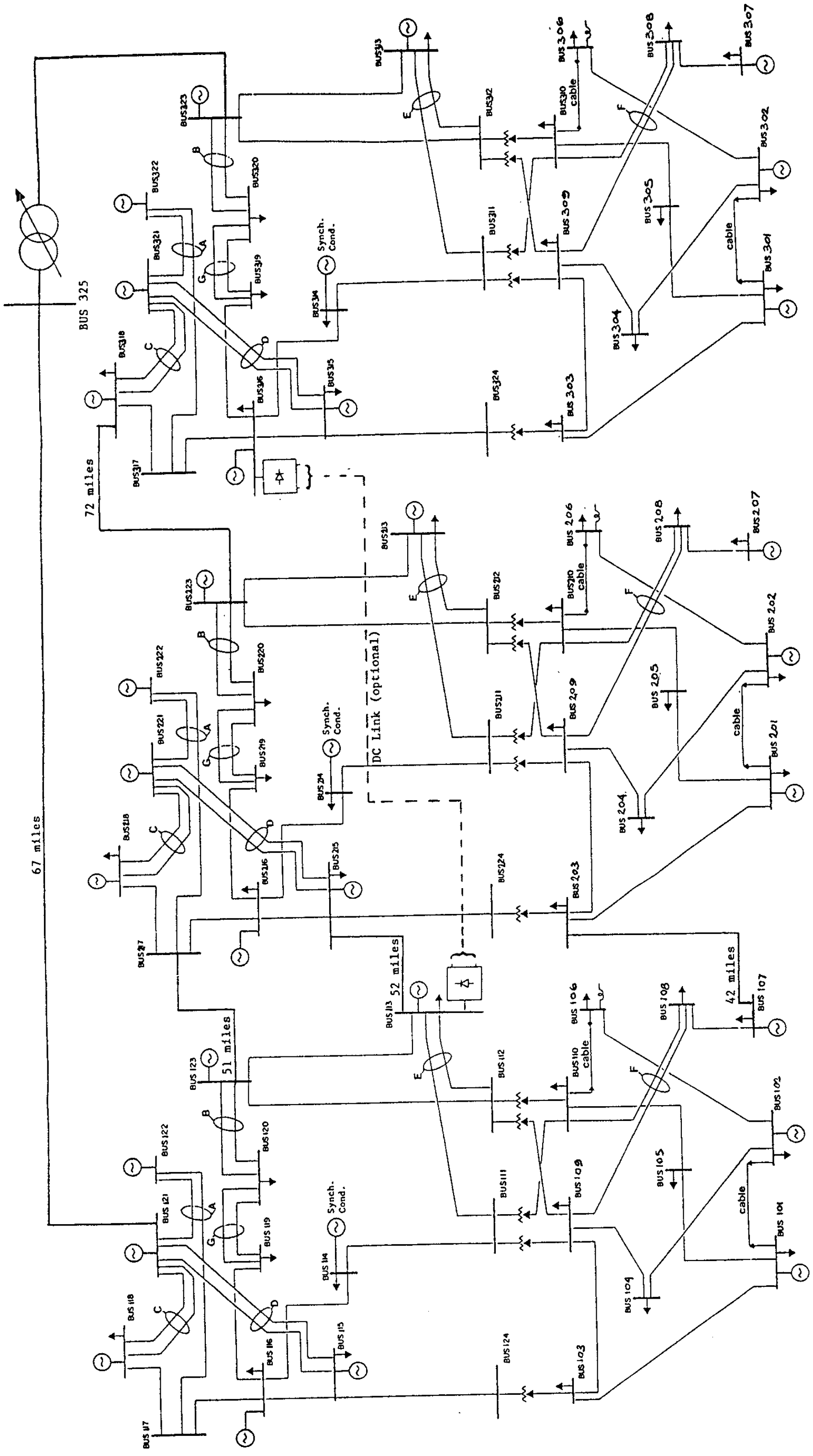

Figure 3.1: RTS-96 topology [22]

01/07 at 12:00 PM the load is:

$$L_{b=108} = (L_{yearweek=27} = 75.5\%) \times (L_{dayofweek=friday} = 94\%)$$
$$\times (L_{hour=12PM} = 93\%) \times 108 = 71.28MW \quad (3.1)$$

Figure 3.2 displays the total system load throughout the month of July.

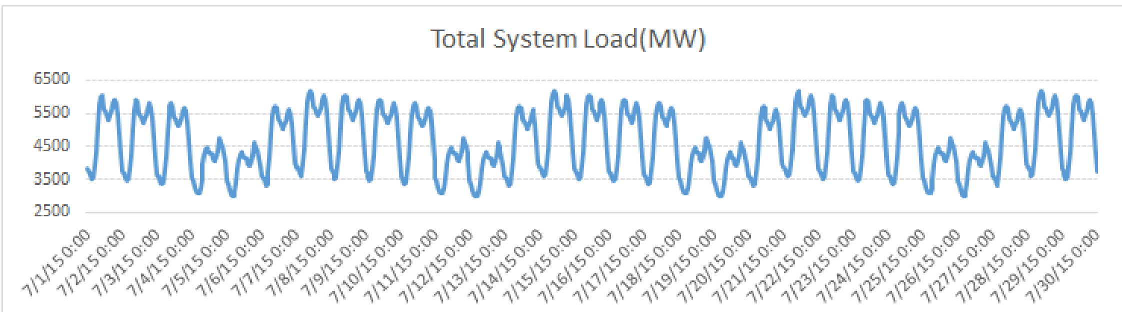

Figure 3.2: System Total Load over the month of July (MW)

When the models are run under a sub-hourly level,the inter-hour time periods follow the interpolation between the hours with an additional perturbation, following an uniform distribution of $[-Pr, +Pr]\%$, where Pr is a parameter in the range of [0,100]. The objective is to capture the ramping behaviour of NVERs on a sub hourly level. Figure 3.3 shows a difference between load curve on a 60 minute and 15 minute planning level.

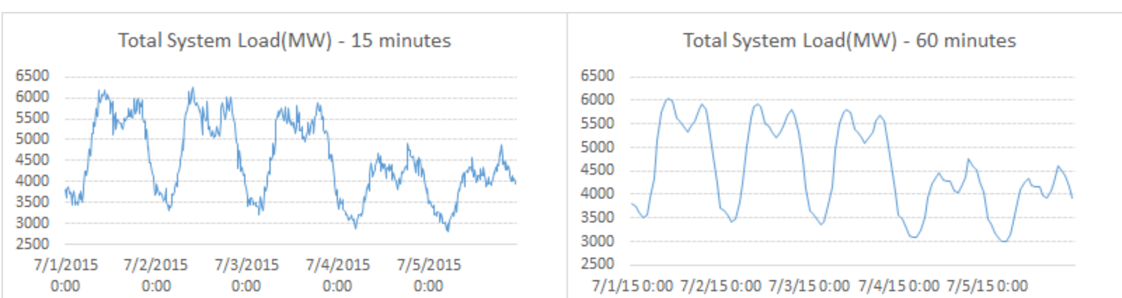

Figure 3.3: System Load for 5 days in July under 60 and 15 minutes level

The original RTS-96 system has 87 generators distributed across the test field, with the following generator type distribution:

- 27 coal/steam generators
- 18 hydro generators
- 24 oil/steam generators
- 15 nuclear generators
- 3 sync generators (not considered for this study)

The total peak load is 8550MW while the total generation capacity is 9975MW. This project assumes the following regarding the data:

- All the buses follow the same behaviour. Therefore they have positive correlation.
- The load profile is the same for every year.
- The peak load is constant and deterministic. No stochastic factor is considered in this study.

3.1.2 Renewable Generators Data

Although RTS-96 has most of necessary data for this project, it does not contain any information of renewable generation. Therefore we found necessary to integrate wind and solar data in the field to build realistic results when evaluating the impact of VER's in the proposed models. The wind and solar profiles states the generation capacity for these renewable resources thorough one year, and it is based on historical availability from the last 5 years in Texas. The data taken was from the Electric Reliability Council of Texas - ERCOT. The geographic renewable potential in Texas were considered for each bus in the system, both for solar and wind generators.

Wind Profile

Figure 3.4 shows the Texas Annual Average Wind speed and the relative geographic positions of RTS-96 buses [22]. The flat northern border is know as the "panhandle" because the state of Oklahoma, in north of Texas, is shaped like a pan. The handle of this pan is where there's most of wind potential in state. In result, most of the new generators are being installed in northwest.

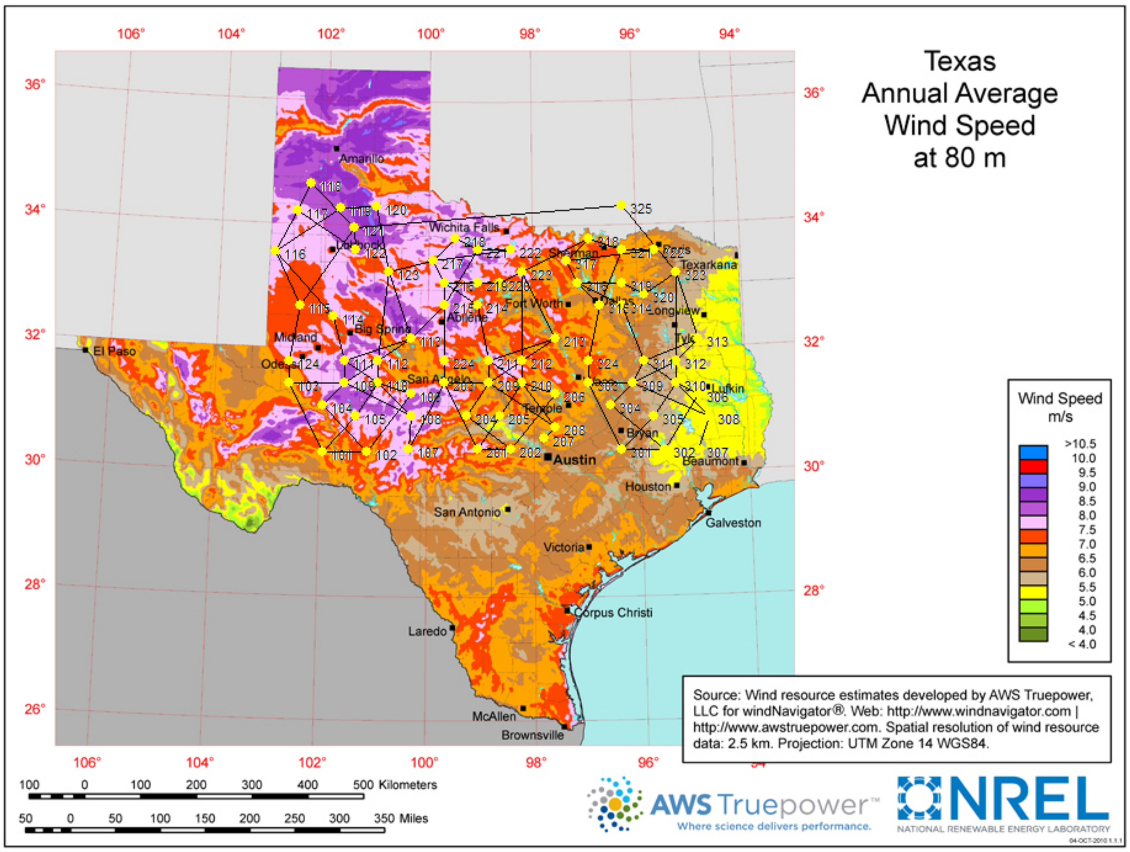

Figure 3.4: Wind Potential for Texas with RTS-96 Bus Locations. Adapted from [3]

To build the wind potential, each bus were associated to a Texas city or region along with the average historical wind generation for the past 5 years. The studied data is freely shared by ERCOT [6]. Therefore each location has a wind potential on an hourly level throughout an entire year. In sub-hourly levels the availability follows the interpolation between the hours followed by an uniform perturbation, using the same logic as load. That said, the real generation for any wind generator is a factor of the percentage of the nameplate capacity followed by the profile where it is located. Figure 3.5 shows the wind profile for the bus 122 within the month of January.

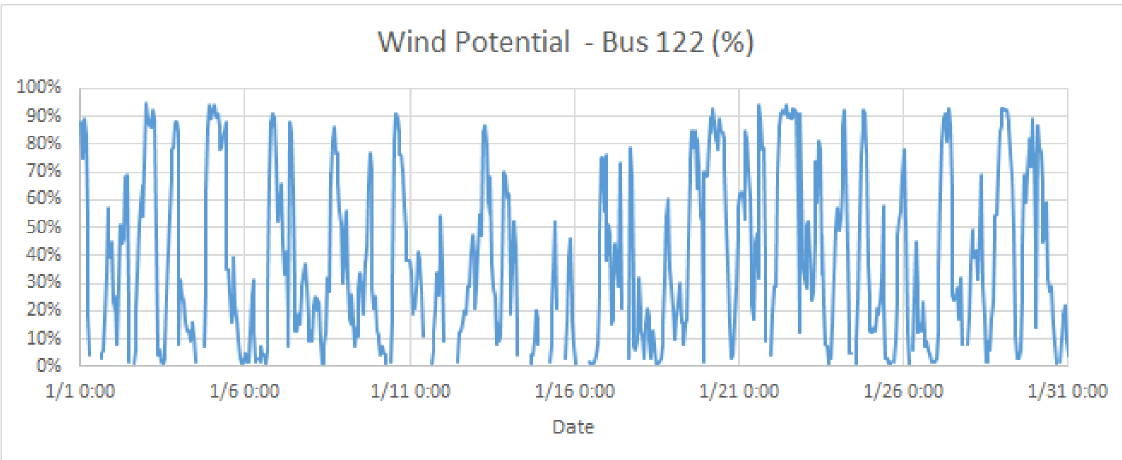

Figure 3.5: Wind Profile for Bus 122 in January

Solar Profile

Figure 3.6 displays the NREL's solar incidence report in the state of Texas and the relative geographic positions of RTS-96 buses.

It is important to notice that the highest incidence profile in state is located in west of Texas, followed by northeast and center. The solar profile construction followed the same logic developed in the wind case. However, only buses located in the mentioned area had their profiles built. As an example, the solar profile for bus 112 (in far northeast of Texas) on January is shown in figure 3.7.

3.1.3 Scenario Description

This project studies 3 different generators scenarios under the same demand profile from RTS-96 data. The distribution is adapted from Shavel et al., that describes

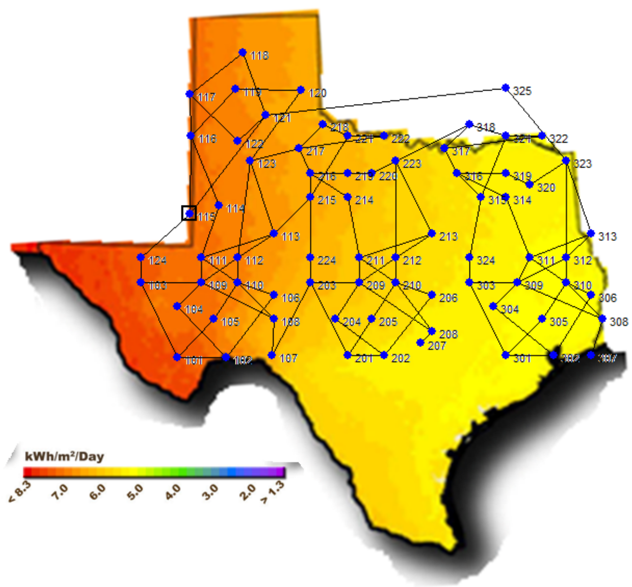

Figure 3.6: Solar Potential for Texas with RTS-96 Bus Locations. Adapted from [13]

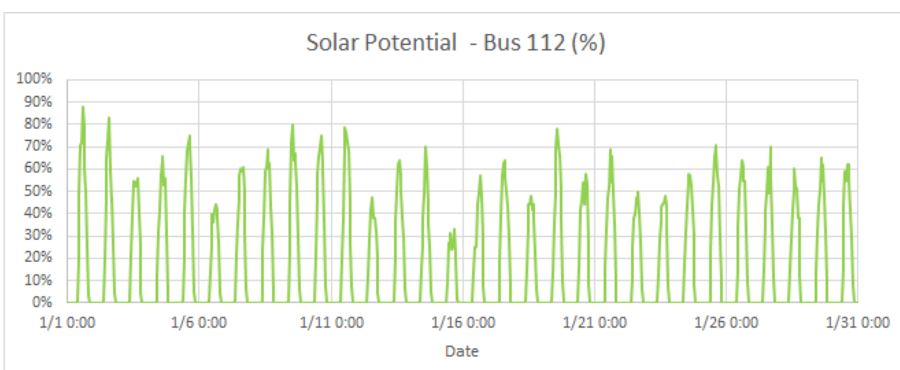

Figure 3.7: Solar Profile for Bus 112 in January

the technical and economical potentials of exploring natural gas and VERs in the state of Texas [20].

Scenario 1: Reference

This scenario captures the existing ERTOC capacity mix. 88% of generation comes from non-renewable energy sources. The remaining capacity is filled by wind generators, located in the buses that has the Texas Northwest's wind potential (Buses 111-124).

Scenario 2: Stronger Federal Carbon Rule

Scenario 2 is build based on column "2032 Total" of table IV-10 in [20]. This scenario is described as follows:

> "Our scenario with a strong federal carbon rule requires existing coal plants to capture and sequester 90% of their CO2 output.(...) As one would expect, this case shows that most of the ERCOT coal plant fleet retires in 2025, the year we assume the carbon rule goes into effect. At this point, 16 GW of coal capacity providing more than 30% of all ERCOT energy rapidly shifts to gas and renewable supply sources: 6 GW of new CC capacity and 3 GW of new wind capacity. In the next several years, another 3 GW of CC capacity is added, along with another 19 GW of wind. Solar becomes rapidly cost-effective in this scenario and quickly rises to over 8 GW installed by 2029. For the remainder of the scenario horizon, all additional load growth is met by solar and wind additions.

In essence, 44% of the generation is provided by natural gases, followed by 42% of NVERs and 14% of other sources. Most of the wind generators are located at buses 111-124, with some in 211-224. Solar generators are at buses 101-110.

Scenario 3: "Almost Green World"

This scenario is an extreme case of Scenario 2. All coal, nuclear and oil/steam generators are not part of the system anymore. The grid runs entirely on wind and solar, with natural gases for ramping, flexibiliy and backup, i.e, to complete the demand whether there is not enough wind and solar to fulfill the load. Wind and solar generators are located throughout the map, following the concentration based on wind and solar profiles from figures 3.6 and 3.4.

Scenario 4: "Almost Green World"

In this scenario all the natural gases are replaced by battery storages. The generation is 100% provided by wind and solar generators, with nameplate capacity bigger than Scenario 3.

Generation per Scenario

The nameplate capacity of base case scenario described by Shavel et al. is 82,949 MW, where for RTS-96 is close to 10,000 MW. Therefore all absolute generator type capacities were adapted to the new baseline and the rates by type were mantained. The result is in table 3.1.

	Scenario 1		**Scenario 2**		**Scenario 3**	
	MW	**%**	**MW**	**%**	**MW**	**%**
Nuclear	660	6	440	4	0	0
Coal	2530	23	220	2	0	0
Oil/Gas	1650	15	880	8	0	0
NGCC	4180	38	4400	40	2287	21
NGTC	2090	6	440	4	404	3
Wind	660	12	3630	33	7934	60
Solar	1320	0	900	9	2824	16
Total	**11000**	**100**	**11000**	**100**	**13452**	**100**

Table 3.1: Total capacity expressed in MW and percentage for each generator type in three scenarios.

3.2 Models

This thesis covers the Economic Dispatch and Unit Commitment models, developed exhaustively in the literature.

3.2.1 Indices and Sets

$g \in \mathcal{G}$	Set of generators
$b \in \mathcal{B}$	Set of buses
$g \in \mathcal{G}^{NR}$	Subset of non-renewable generators
$g \in \mathcal{G}^{R}$	Subset of renewable generators
$gt \in \mathcal{GT}$	Set of generator types
$u \in \mathcal{U}$	Set of unit groups
$l \in \mathcal{L}$	Set of transmission lines
$rr \in \mathcal{RR}$	Set of reserve requirements
$rp \in \mathcal{RP}$	Set of reserve products
$t \in \mathcal{T}$	Set of time periods
$g \in \mathcal{G}^{\lfloor}$	Set of generators in each bus b

3.2.2 Parameters

$D_{b,t}$	Load at bus b in time t
C_g	Generation cost for generator g ($ / MW) t
S_g	Start-up cost for generator g
R_g^{up}	Ramp up limit for generator g
R_g^{down}	Ramp down limit for generator g
G_g^{max}	Maximum generation capacity for generator g
G_g^{min}	Minimum generation capacity for generator g
T_l^{min}	Minimum transmission of transmission line l
T_l^{max}	Maximum transmission of transmission line l
$P_{g,t}^{R}$	Power generation of renewable generator g in time t
U_g^{up}	Minimum uptime of generator g (hours)
U_g^{down}	Minimum downtime of generator g (hours)

Note 1: The generation of renewable resources are not in the decision variables. The developed models only decides the generation for non-renewable resources. Therefore the generation is considered a deterministic parameter, not a variable in the model.

3.2.3 Variables

$P^{NR}_{g,t}$	Power generation of non-renewable generator g in time t (MW)
$T_{i,j,t}$	Power transmitted from bus i to bus j in time t (MW)
$T^{loss}_{i,j,t}$	Power loss in transmission from bus i to bus j in time t (MW)
$S_{g,t}$	On/off status of generator g at time n
$S^{on}_{g,t}$	Start-up status of generator g at time n
$S^{off}_{g,t}$	Shut-down status of generator g at time n
$V^{-}_{b,t}$	Under generation slack variable at each bus b in time t
$V^{+}_{b,t}$	Over generation slack variable at each bus b in time t

3.2.4 Models

The economic dispatch model satisfies the load and transmission requirements at a minimum cost, following operational requirements such as generation, transmission and ramp limits. In this model, we assume that the commitment decisions has been already made.

Simple Economic Dispatch Model

$$min \quad \sum_{t\in T}\sum_{g\in G^{NR}} P^{NR}_{g,t}C_g + \sum_{t\in T}\sum_{b\in B} V^{-}_{b,t} + \sum_{t\in T}\sum_{b\in B} V^{+}_{b,t} \tag{3.2a}$$

$$s.t. \quad \sum_{t\in T} P^{NR}_{g,t} + \sum_{t\in T} P^{R}_{g,t} + \sum_{t\in T} V^{-}_{b,t} = \sum_{t\in T} D_{b,t} + \sum_{t\in T} V^{+}_{b,t} \ \forall t \in T \tag{3.2b}$$

$$P^{NR}_{g,t} - P^{NR}_{g,t-1} \le R^{up}_g \qquad \forall t \in T, g \in \mathcal{G}^R \tag{3.2c}$$

$$P^{NR}_{g,t-1} - P^{NR}_{g,t} \le R^{down}_g \qquad \forall t \in T, g \in \mathcal{G}^R \tag{3.2d}$$

$$G^{min}_g \le P^{NR}_{g,t} \le G^{max}_g \qquad \forall t \in T, g \in \mathcal{G}^R \tag{3.2e}$$

The constraint 3.2b states the energy balance in every time. The constraints 3.2d and 3.2c states that every generator has to obey the ramp limits. The constraint 3.2e states the generation limits for each generator. The use of slack variables $V^-_{b,t}$ and $V^+_{b,t}$ is necessary to always have feasible solutions, and it is important for scenarios where there is a huge renewable penetrations, when there's an abrupt variation of generation and there is a over or under generation.

Economic Dispatch with Transmission Constraints

In this case, the model has to consider transmission limits and losses, without transmission costs associated. The objective function 3.2a remains the same, and the constraints 3.2c, 3.2d and 3.2e are als used. The constraint 3.2b is replaced by

$$\sum_{g \in G^b} P^{NR}_{g,t} + \sum_{g \in G^b} P^{R}_{g,t} + \sum_{b^{in} \in B} T_{b^{in},b,t} + V^-_{b,t} = D_{b,t} + V^+_{b,t} + \sum_{b^{out} \in B} T_{b,b^{out},t} \ \forall b \in B, t \in t \tag{3.3a}$$

$$T^{min}_l \leq T_{b^{in},b^{out},t} \leq T^{max}_l \qquad \forall b \in B, t \in t \tag{3.3b}$$

Constraint 3.3a guarantees that the energy balance is always satisfied for every bus: everything that is generated and received from other buses should be equal to what is loaded and sent throughout the line with the respective losses. If this balance is not satisfied then it is represented in the slack variables. (TODO: put lossed in the equation). The constraint 3.3b defines the transmission bounds for each line.

Economic dispatch model with unit commitment constraints

Unit commitment is the decision of consider the sets of generators that are turned on and off for the planned time horizon. The model includes decision variables to capture "on" and "off" states for thermal generators in each time period,along with the start-up and shut-down decisions. [17]. The set of constraints are added to the previous model, and the binary nature of the variables makes the problem an MIP, naturally harder to solve computationally [15].

$$S_{g,t} = S^{on}_{g,t} - S^{off}_{g,t} + S_{g,t} \qquad \forall g \in \mathcal{G}^{NR}, t \in \mathcal{T} \tag{3.4a}$$

$$\sum_{i=t}^{t+U^{up}_{g}-1} S_{g,t} \geq S^{on}_{g,i} U^{up}_{g} \qquad \forall g \in \mathcal{G}^{NR}, t \in \mathcal{T} \tag{3.4b}$$

$$\sum_{i=t}^{t+U^{down}_{g}-1} (1 - S_{g,t}) \geq S^{off}_{g,i} U^{down}_{g} \quad \forall g \in \mathcal{G}^{NR}, t \in \mathcal{T} \tag{3.4c}$$

Constraint 3.4a specifies the logical condition between the binary variables, assuring that a generator can not be on if it was not turned on. The same is valid for turning it off. Constraints 3.4b and 3.4c forces the generator to follow their minimum downtime and uptime periods when they are turned on or off.

3.3 Implementation

Here write about how it was implemented, in AIMMS, put some running times in a table, some images, put a brief description about what is AIMMS and why it is used, and etc.

Chapter 4

Analysis

In the analysis make all the scenario runs, describe the data.

Chapter 5

Conclusion

Bibliography

[1] D. Bertsimas, E. Litvinov, X. A. Sun, Jinye Zhao, and Tongxin Zheng. Adaptive robust optimization for the security constrained unit commitment problem. *Power Systems, IEEE Transactions on*, 28(1):52–63, 2013. ID: 1.

[2] Mary B. Cain, Richard P. Oneill, and Anya Castillo. History of optimal power flow and formulations. *Federal Energy Regulatory Commission*, 2012.

[3] The Wind Coalition. *Texas Wind Energy Facts*. Available at http://windcoalition.org/texas-wind-energy-facts/. 04/03/2016.

[4] David Connolly, Henrik Lund, Brian Vad Mathiesen, and Martin Leahy. A review of computer tools for analysing the integration of renewable energy into various energy systems. *Applied Energy*, 87(4):1059–1082, 2010.

[5] J. P. Deane, G. Drayton, and B. P. Gallachir. The impact of sub-hourly modelling in power systems with significant levels of renewable generation. *Applied Energy*, 113:152–158, 1 2014.

[6] ERCOT. *Generation*. Available at http://www.ercot.com/gridinfo/generation.

[7] E. B. Fisher, R. P. O'Neill, and M. C. Ferris. Optimal transmission switching. *Power Systems, IEEE Transactions on*, 23(3):1346–1355, 2008. ID: 1.

[8] L. L. Garver. Power generation scheduling by integer programming-development of theory. *Power Apparatus and Systems, Part III.Transactions of the American Institute of Electrical Engineers*, 81(3):730–734, 1962. ID: 1.

[9] Jeremy Hargreaves, Elaine K. Hart, Ryan Jones, and Arne Olson. Reflex: An adapted production simulation methodology for flexible capacity planning. *Power Systems, IEEE Transactions on*, 30(3):1306–1315, 2015.

[10] Chioke Harris, Jeremy P. Meyers, and Michael E. Webber. A unit commitment study of the application of energy storage toward the integration of renewable generation. *Journal of Renewable and Sustainable Energy*, 4(1):013120, 2012.

[11] John G. Kassakian, Richard Schmalensee, G. Desgroseilliers, Timothy D. Heidel, K. Afridi, AM Farid, JM Grochow, WW Hogan, HD Jacoby, and JL Kirtley. The future of the electric grid. *Massachusetts Institute of Technology, Tech.Rep*, 2011.

[12] A. Khodaei and M. Shahidehpour. Transmission switching in security-constrained unit commitment. *IEEE Transactions on Power Systems*, 25(4): 1937–1945, 2010. ID: 1.

[13] NREL. *NREL: Dynamic Maps, GIS Data, and Analysis Tools - Renewable Energy Technical Potential*. Available at http://www.nrel.gov/gis/repotential.html. Acessed on 04/03/2016.

[14] C. O'Dwyer and D. Flynn. Using energy storage to manage high net load variability at sub-hourly time-scales. *IEEE Transactions on Power Systems*, 30 (4):2139–2148, 2015. ID: 1.

[15] James Ostrowski, Miguel F. Anjos, and Anthony Vannelli. Tight mixed integer linear programming formulations for the unit commitment problem. *IEEE Transactions on Power Systems*, 27(1):39, 2012.

[16] Narayana Prasad Padhy. Unit commitment-a bibliographical survey. *Power Systems, IEEE Transactions on*, 19(2):1196–1205, 2004.

[17] B. Palmintier and M. Webster. Impact of unit commitment constraints on generation expansion planning with renewables. In *Power and Energy Society General Meeting, 2011 IEEE*, pages 1–7, 2011. ISBN 1944-9925. ID: 1.

[18] Hadi Saadat. *Power system analysis*. WCB/McGraw-Hill, 1999.

[19] Hossein Safaei and David W. Keith. How much bulk energy storage is needed to decarbonize electricity? *Energy and Environmental Science*, 8(12):3409–3417, 2015.

[20] Ira Shavel, Peter Fox-Penner, Jurgen Weiss, Ryan Hledik, Pablo Ruiz, Yingxia Yang, Rebecca Carroll, and Jake Zahniser-Word. Exploring natural gas and renewables in ercot, part ii. 2014.

[21] Walter Short, Patrick Sullivan, Trieu Mai, Matthew Mowers, Caroline Uriarte, Nate Blair, Donna Heimiller, and Andrew Martinez. Regional energy deployment system (reeds). *Contract*, 303:275–3000, 2011.

[22] Paul Wong, P Albrecht, R Allan, Roy Billinton, Qian Chen, C Fong, Sandro Haddad, Wenyuan Li, R Mukerji, Diane Patton, et al. The ieee reliability test system-1996. a report prepared by the reliability test system task force of the application of probability methods subcommittee. *Power Systems, IEEE Transactions on*, 14(3):1010–1020, 1999.

[23] Hatim Y Yamin. Review on methods of generation scheduling in electric power systems. *Electric Power Systems Research*, 69(2):227–248, 2004.

[24] Yuan Zhiqiang, Hou Zhijian, and Jiang Chuanwen. Economic dispatch and optimal power flow based on chaotic optimization. In *Power System Technology, 2002. Proceedings. PowerCon 2002. International Conference on*, volume 4, pages 2313–2317 vol.4, 2002. ID: 1.

[25] H. Zhong, Q. Xia, Y. Wang, and C. Kang. Dynamic economic dispatch considering transmission losses using quadratically constrained quadratic program method. *IEEE Transactions on Power Systems*, 28(3):2232–2241, 2013. ID: 1.