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On the role of load shedding in facilitating the integration of renewable energy technologies in small island developing states – the Aruba case

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Abstract

The exploitation of the abundant renewable energy potential in most Small Island Developing States (SIDS) will be crucial in the near future for safeguarding their access to affordable energy, and the preservation of their eco-system. Some SIDS have already introduced renewable energy technology (RET) for exploiting primarily the available wind and solar energy. However, these islands are dealing with the intermittent nature of these renewable energy sources by only compensating the energy generation part of the electrical network. This limits the penetration level of RETs based on the flexibility of the supply side. The other option for compensating the variable output of RETs is demand side management (DSM), and even though the theory behind this subject is well documented, little attention has been given to actual SIDS cases. Therefore, this paper presents an assessment of the DSM potential in Aruba, because it is currently one of the few SIDS with a significant penetration level of RETs. This assessment relies on a mixed research method approach, based among other things on Linear Programming techniques, which can also be easily applied to other SID-cases. The results suggest that the current DSM potential for Aruba is a compensation capability of approximately 12,7-17,8 MW within 10 minutes, if only the largest consumer, i.e. the hotel sector, is involved. Furthermore, the proposed DSM program of directly shedding the air-conditioning load of the hotel sector was found technically and economically feasible although customer related barriers may hamper implementation.

Keywords: load shedding, integration, wind energy, small island developing states, Aruba

1. Introduction

There are approximately 52 small island developing states (SIDS), which share similar characteristics related to energy supply including:

- lack of conventional energy resources
- abundance of renewable energy sources
- small dimension of the energy market.
- high dependency on fossil fuels
- diseconomies of scale

The combined effect of these characteristics makes power production not only extremely expensive but also bears financial risks in the long term [1-4].

Interestingly, SIDS have the opportunity to harness energy out of their renewable sources which, as indigenous resources, do not require costly fuel imports [5-8]. The exploitation of such resources will be crucial in the near future to safeguard the access to affordable energy and the preservation of the islands eco-system. However, these islands are dealing with the intermittent nature of these renewable energy sources by only compensating the energy generation part of the electrical network. This limits the penetration level of RETs based on the flexibility of the supply side. Specifically the technical ability of an electricity system to compensate the variable output of RETs is restricted by the ability of its generating units to alter their power output accordingly, up to the point where imbalances may occur. In electricity system it is essential that power generation (supply) and the electrical load (demand) are close to equal to avoid overloading or blackouts of network components. Traditional solutions to prevent such situations require investments in expensive fast spinning reserves, interconnections or storage technologies. Another option to compensate the variable output of RETs is demand-side management (DSM). It implies the direct control of customer's appliances to reduce or increase loads during system events (load shedding).

Different forms of DSM can be applied to address major issues including: reduction of energy consumption, cost reduction, environmental and social improvement. Furthermore it can increase system reliability, resolve network issues and improve markets [9, 10]. However, little attention has been given to SIDS-cases where DSM is considered as a means to facilitate the integration of RETs. In addition there is not enough evidence to provide reliable estimates of the technical and economic potential and to account for the customer's willingness to participate.

Aruba is currently one of the few SIDS with significant penetration of wind energy (14%). The build of a similar second wind park is high on the political agenda and could increase this share to 30% giving rise to the following uncertainties: 1) the technical capabilities of the system to maintain the balance between supply and demand and 2) the potential of DSM to facilitate this. Currently it is unknown to what extent DSM can facilitate the integration of additional wind energy on the Aruban electricity system.

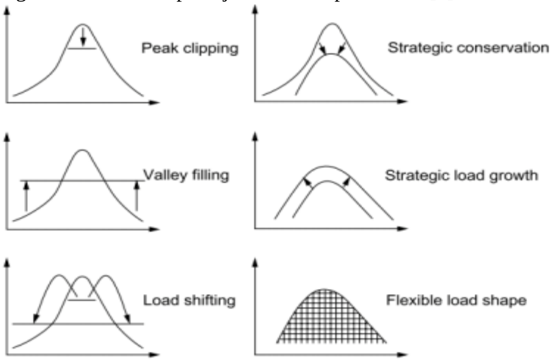
Therefore, this article presents a multidisciplinary assessment of DSM, and in particular of load shedding for the island of Aruba.

This paper is organized as follows. Section 2, introduces the theory on DSM and explains the choice for direct control load shedding. In section 3, the methodology is presented. Section 4 states the results. Section 5, discusses these results and states conclusions and recommendations.

2. Theory DSM

In generating power, the concept so far has been straightforward: if society demanded more power, the power companies would simply find a way to supply electricity to end-users by building more generation facilities. This concept of doing business has been labelled as supply-side management. Demand-side management describes the activities designed to influence customers energy behaviour in such a way that the load shape curve of the utility company can be modified to produce power in an (technically and economic) optimal way [11]. The choice for a DSM program depends on what type of problem DSM intends to solve and can be determined by two factors: the load shape objective and the time-scale. The load shape objective can include the following (Figure 2-1): decrease load, increase load or shift load. The time-scale largely defines within what time-scale (seconds, minutes, hours, weeks) the load has to be altered (Table 2-1).

Figure 2-1: Load shape objectives. Adapted from: [9]



Furthermore, some DSM programs are characterized with short response times (seconds) to response times of days and months. The classification of DSM programs can be either described as direct or indirect [12, 13]. In incentive based programs (IBP), the aim is to alter the electricity consumption of certain load profiles in response to a system event (i.e. variable output of wind energy). In a classical IBP a utility is able to control the customer's appliances, usually based on a contract, during critical system conditions [13]. In addition the participating customers receive participation payments usually as a bill credit or discount rate for their electricity usage. In market based programs participants are rewarded for their performance depending on the amount of flexible load they offer during critical system conditions.

Table 2-1: Classification of DSM programs. Adapted from: [12, 13]

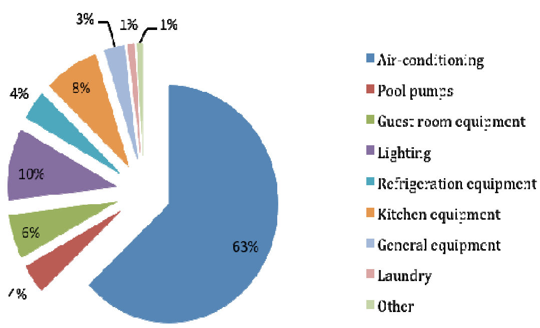
Incentive based programs (IBP)	***Price based programs (PBP) (indirect)***
• Classical (direct) o Direct load control o Interruptible/ curtailment programs • Market based o Demand bidding o Emergency DR o Capacity market o Ancillary services market	• Pricing programs o Time of use tariff o Real time pricing o Critical peak pricing o Extreme day pricing o Extreme day critical peak pricing • Rebates and subsidies • Education programs

Price based programs (PBPs) assumes that customers will alter their consumption of electricity in response to changes in its pricing. The pricing in these programs is dynamic, so the rates are following the real costs of electricity [12, 14]. In general, the customer's load is not interrupted and no (financial) penalties are amerced when loads are not altered.

In this research, the integration for wind energy is the key driver for het interest in DSM. The reliability of the Aruban electricity system is endangered during moments of sudden and severe wind decreases. This requires a DSM measure that is able to decrease loads within a short period of time. This excludes the option of price-based programs because it assumes the voluntary response of customer to an indirect incentive.

On the other hand, direct load control programs provide a utility the opportunity to directly reduce the customer's appliances, e.g. water heater, air conditioning and public lighting on a short notice by sending signals [12]. Participating customers will receive upfront discount rates or incentive payments. The capacity of the loads and the availability of the loads must be sufficient. The Aruban hotel sector represents 30% of the total electricity demand and 60-80% of this demand is related to air-conditioning load (see Figure 2-2). This article focuses on the potential of shedding air-conditioning loads of the Aruban hotel industry in compensating sudden and severe wind power decreases.

Figure 2-2: Average electricity use of an Aruban hotel. Calculations based on: [15-17]



3. Methodology

We performed a technical analysis of the Aruban electricity system through Linear Programming. Furthermore a cost benefit analysis was drawn for the additional wind park including various reliability investments scenarios and various interviews with General Managers and Directors of Engineering of the hotel industry on the willingness to participate in the proposed load shedding program.

Technical analysis

Additional wind energy will affect the reliability of the electricity system, mainly caused by additional variation. To quantitatively assess the effects of additional wind energy the dispatch of generating units, and their characteristics are analysed under demand patterns and wind power output based on historical data. This analysis is based on a Unit Commitment (UC), formulated as a Linear Programming (LP) problem. UC has been used extensively for the last decades as a means to: simulate the integration of RETs, assess system flexibility and to assess the contribution of DSM to power system flexibility [18-21]. The modelling approach we defined is: optimization of supply sources according to a merit order, to supply demand within the technical constraints of the system (i.e. limits on generation capacity, ramp rates, start-up and shutdown times). For the development of the model we used a software-modelling package called Linny-R, which enables us to model, implement and adapt such complex LP problems. The objective function was designed to minimize generation costs, including variable costs and start-up costs. And is expressed in the following formula:

MINIMIZE:

$$\alpha * P_{unit,1}(t) + \beta * P_{unit,2}(t) + \gamma * P_{unit,x}(t)$$

With α being the variable costs per unit of production (measured in $/kW) at time t related to the production level of $P_{unit,1}$ at time t and so on. Virtual costs were assigned to reflect the actual order in which the production capacity is used. By minimizing this function, the realistic unit commitment order is followed when solving the LP. The following five constraints were considered in the LP formulation. The generation of electricity must be equal to the demand with P_{total} being the total power production (measured in MW) at time t and D_{total} the total demand (measured in MW) at time t (eq.1). The total production level at a certain time is limited by the amount of units that can produce electricity with P_{fossil} being the total amount of electricity that is produced through fossil fuel based units (measured in MW) at time t and P_{wind} the total electricity that is produced by wind energy (measured in MW) at time t (eq.2). Another constraint is that wind energy has priority over fossil fuel based electricity and results in the residual demand that must be compensated by the fossil production (eq.3). The electrical output of a unit is limited by its minimum and maximum capacity with $P_{unit,x}$ being the electricity production of unit x (measured in MW) at time t and a,b being the lower- and upper bound of the units generating capacity (measured in MW). (eq.4). The limited amount of electrical output that can be decreased or increased per time unit is limited by the ramp rates. With $P_{unit,x}(t)$ being the electricity production of unit x at time t *and* $P_{unit,x}(t\text{-}1)$ being the electricity production of unit x at time *t-1* (both measured in MW) and R_{up} and R_{down} being the ramp up and ramp down rate, that limits the increase or decrease of the production of unit x per time-step t (measured in MW/min) (eq. 5-6).

(1) $$P_{total}(t) = D_{total}(t)$$

(2) $$P_{total}(t) = P_{fossil}(t) + P_{wind}(t)$$

(3) $$D_{total}(t) - P_{wind}(t) = P_{fossil}(t)$$

(4) $$a \leq P_{unit,x}(t) \leq b$$

(5) $$P_{unit,x}(t) - P_{unit,x}(t-1) \leq R_{up}$$
as generation increases

(6) $$P_{unit,x}(t) - P_{unit,x}(t-1) \leq R_{down}$$
as generation decreases

The constraints have been specified according to the unit characteristics presented in Table 3-1. DSM is also incorporated in the model as a virtual reserve that is only dispatched at times of imbalances. This enables us to identify the technical requirements necessary to compensate such imbalances in terms of frequency (#/yr), amount of power (MW) and the duration (min). These identify the technical potential of the shedding of air-conditioning load of the hotel industry.

Table 3-1: Unit characteristics. Source: WEB N.V.

Characteristics	*Recip[1] (I-II)*	*Recip III*	*VAASA*	*TG[2] 6,7*	*GT[3]*
Ramp up[4]	0,8	0,9	0,6	1,5	1,2
Ramp down	1,5	1,8	1,2	1,5	1,2
Max gen[5]	7	10	6	36	18
Min gen	5	7	5	15	3
Start-up failure	25%	25%	25%	0	0
Start-up time[6]	15	15	30	360	15
Shutdown time	2	2	2	240	15
Min up time	15	15	15	1440	15
Min down time	15	15	15	1440	15

Cost benefit analysis

The economic feasibility of load shedding as a reliability measure depends the associated costs and benefits compared to other suitable supply side measure. In order to analyse this, the following costs are taken into account:
i) capital costs ii) the net present value (NPV) and iii) the total annualized costs including a capital recovery factor (CRF). The costs of load shedding are estimated through the study of Bradley et al. 2012 [22] and complemented with information on current market prices[7]. We have evaluated various non-battery, battery and super capacitor storage technologies according to their applicability on the identified simulation requirements. For each storage technique, the costs of storage, conversion, balance of plant, capital costs, operations and maintenance have been estimated through the study of Sundararagavan and Baker (2012) [23] and calculated with use of the developed method by Poonpun and Jewell (2008) [24].
The economic feasibility for any measure that aims to reduce system intermittency depends on the available capital. As a result, the costs per reliability technology may not exceed the benefits of the additional wind farm itself. Many studies use the notion of 'levelized costs' to analyse the economic feasibility of wind energy. This, as discussed by Keay (2013) [25] does not account for the additional investments in grid- or reliability measures associated with the integration of additional wind energy. However, this research does incorporate these costs in the analysis and provides a more accurate estimation. The following formula explains the relations between these costs and benefits:

(1) Net system benefits = system benefits – system costs
(2) System benefits = reduced fuel costs
(3) System costs = initial investments costs (wind) + grid investments costs + reliability investment costs

Each reliability technology defines an investment scenario. The scenario with the least investment costs results in the highest net system benefits.

Customer willingness to participate

The success of such a program depends for a great deal on the willingness of the hotel industry to participate. Therefore several interviews with General Managers and Directors of Engineering were conducted to identify possible barriers or opportunities related to the implementation of load shedding. Although little is documented on such particular barriers, we've suggested that there exist mutual barriers and relations with other forms of DSM. Consequently, the extensive literature review report of the United Nations Industrial Development Organisation (UNIDO) (2011) [26] on barriers to industrial energy efficiency was used to define and explain possible barriers and structure the interviews. The following barriers were used

i. Bounded rationality: suggests that actors are not able to always act fully rational, and that the inability to do so will results in a general state of satisficing, in which solutions that may or not be optimal are chosen if they meet minimum requirements
ii. Financial- and technical risk: risks associated with measures that require large investments may be hedged by short-term payback periods, which lead to less inefficient investments and innovative, non-familiar technologies may be subject

[1] Recip phase I&II included 6 generating units, phase III 4 units
[2] TG: Turbine Generators
[3] GT: Gasturbine
[4] Ramp rates in (MW/min)
[5] Generation capacity in (MW)
[6] Various time in (min)
[7] Contact with several private entities that offer the service of load shedding and demand response (see openadr.org)

to technical risks (unreliability, break-downs, disruptions), which may outweigh the potential benefits

iii. Imperfect information: the lack of information on energy efficiency opportunities may lead to cost-effective opportunities missed.

iv. Hidden costs: engineering-economic studies fail to account for either the reduction in service associated with energy efficient technologies, or the additional costs associated with their use i.e. general overhead costs of energy management, costs involved in individual technology decision and loss of service associated with energy efficient choices.

v. Access to capital: insufficient capital though external and internal resources lead to borrowing and taking loans and to low payback rates or non- investments.

vi. Split incentives: commonly used notion where landlords own property and tenants hire property. In such cases, there is little incentive for both parties to invest in energy efficiency. The landlord passes the electricity bill on through to the tenant thereby incurring no losses. While tenants may not invest to improve the energy efficiency of properties they do not own and pay a fixed electricity costs per month.

4. Results

This section presents the case-specific results for the Aruban electricity system based on the methodology.

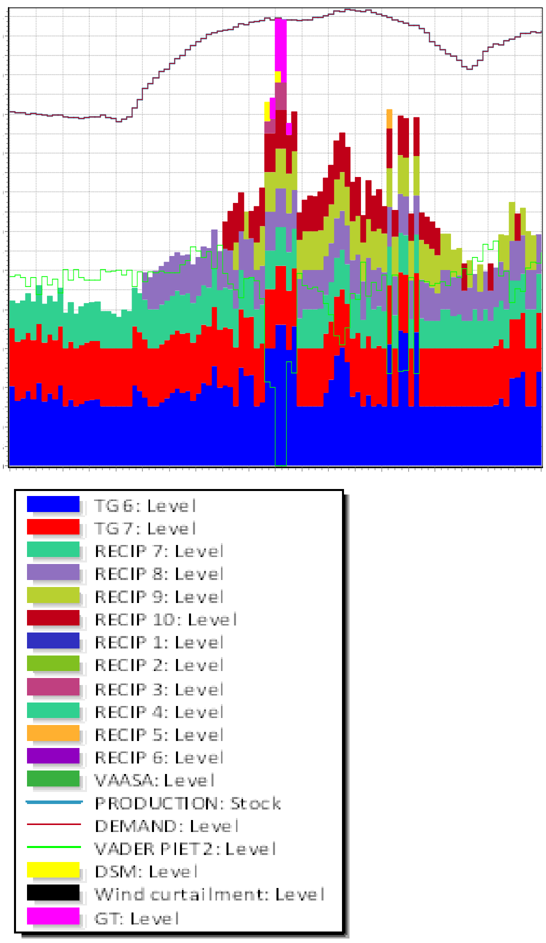
Results: technical analysis

The proposed methodology was applied using a simulation time of a year and with time-step of 10 minutes time-step. The demand and the produced wind power are specified by time-series of historical data (2011) specified per 10 minutes. The additional wind park is modelled as lagging 10 minutes behind on the existing wind farm. The optimization problem was solved using the solver of the software package Linny-R. Three simulation scenarios were performed under various wind generation capacity scenarios, see Table 4-1. During the simulations no imbalances occurred for scenarios with 0 and 30MW of wind generation capacity. In total, seven imbalances occurred for the 60MW wind capacity generation. The most severe imbalance amounted to 8MW and lasted for 10 minutes (see Figure 4-1).

Table 4-1: Specification of imbalance events during the simulation scenarios

Imbalances	*0MW wind*	*30MW wind*	*60MW wind*
Frequency	0	0	7 #/yr
Amount of power	0	0	8 MW
Duration	0	0	10 min

Figure 4-1: Imbalance event during simulation scenario of 60MW wind generation capacity



In addition it is found that the imbalances all occurred during periods of high utilization of reserves combined with a wind decrease between -21 to -25MW per 10 minutes. During such periods, standing reserves are not able to quickly provide sufficient capacity due to the unit constraints. Thus, any solution that aims to mitigate such imbalances must be able to

provide at least 8MW of electricity, within 10 minutes for at least 7 times a year.
The shedding of air-conditioning load of hotels can satisfy the above-mentioned requirements. Shedding AC load seven times a year does not pose any problems. Furthermore, the capacity of the AC load ranges between 12,7-17,8[8] MW and it is possible to gradually shut down or idle AC load within 10 minutes.

Results: cost benefit analysis
The proposed methodology was applied to calculate the costs of load shedding for 18 of the largest hotels in Aruba and for various suitable storage technologies (flywheels, sodium-sulphur batteries, nickel-cadmium batteries and lead acid batteries according to the specified technical requirements. It is concluded that load shedding is the least-costs solution in providing reliability compared to other suitable storage technologies (Table 4-4). As a result, the investment scenario proved to have the highest net benefits $ 6.998.953 (Figure 4-3). The investment is not capital intensive, does not require high upfront costs and is more based on contracts than technologies. The difference in the net system benefits of the load shedding and the scenario with the 2nd highest net benefits (flywheel) can be defined as the avoided system costs (Table 4-2).

Scenario's	*Avoided annual system costs ($/yr)*
Flywheel	728.822
Lead-acid	1.352.959
NaS	3.918.304
Ni-Cd	1.164.142

Table 4-2: Avoided annual system costs of load shedding compared to other technologies

These costs are substantial and can (partly) be allocated as financial compensation or incentive payments for participating customers in the load shedding program. The utility is able to offer a substantial compensation for the low degree of load services required of hotels, resulting is a strong business proposition.

Results: customer willingness to participate
The following main barriers were derived out of the interviews:

i. hidden costs related to guest satisfaction
ii. technical risks relating to implementing load shedding equipment
iii. the issue of control of own operations where hotels may not accept intervention of a third party and require prior notice before a load shedding event (see Table 4-3).

Most of these barriers are caused by a lack of information about the general effects of load shedding.

Table 4-3:Results of the interviews

Barriers	*Claim*
Bounded rationality	Issue of load shedding is subordinate to AC services related to guest satisfaction
Risk	Technical risk, risk of integrating load shedding equipment in existing hotel environment (unreliable, damages etc.) Issue of control of own operations
Imperfect information	Lack of information related to load shedding caused reservations and uncertainties
Hidden costs	Uncertainty on the effects of load shedding directly on the guest satisfaction and indirectly on guest compensation.
Access to capital	-
Split incentives	-

[8] Based on interviews and statistical data provided by N.V. ELMAR. See chapter 4 in de Klerk (2013).

Table 4-4: Summary of required load shedding costs

Technology	Investment costs ($)	Installation costs ($)	Capital costs ($)	O&M costs ($/yr)	NPV* (-$)	Total annualized costs ($/yr)
AC Box	180.000	144.000	324.000	36.000	-	71.573
Software	12.000	-	12.000	4.800	-	6.118
Central control system	200.000	24.000	224.000	2.400	-	26.994
Total load shedding	392.000	168.000	560.000	43.200	953.462	104.685

*NPV calculated with a life time of 15 years and a 7% interest rate

Table 4-5: Summary of required storage technologies costs

Technologies	Storage costs ($)	Conversion costs ($)	Balance of plant costs ($)	Capital costs ($)	Costs O&M ($/yr)	NPV* (-$)		Total annualized costs ($/yr)
Flywheel	1.333.333	3.111.111	800.000	5.244.444	144000	6.483.720	€	833.507
Lead-acid	400.000	4.800.000	800.000	6.000.000	80000	6.428.421	€	1.457.644
NaS	712.000	28.235.294	800.000	29.747.294	112000	30.711.175	€	4.022.989
Ni-Cd	1.596.000	7.384.615	800.000	9.780.615	120000	10.922.243	€	1.268.827

*NPV calculated with the specific life time of the technology (15,6,15,20 years) and a 10% interest rate

Figure 4-2: Associated costs of implementing storage technologies according to technical requirements

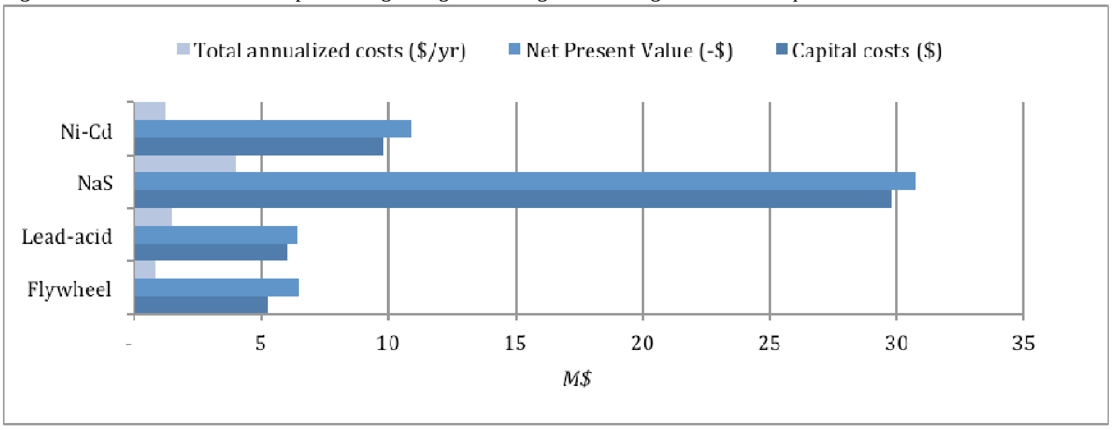
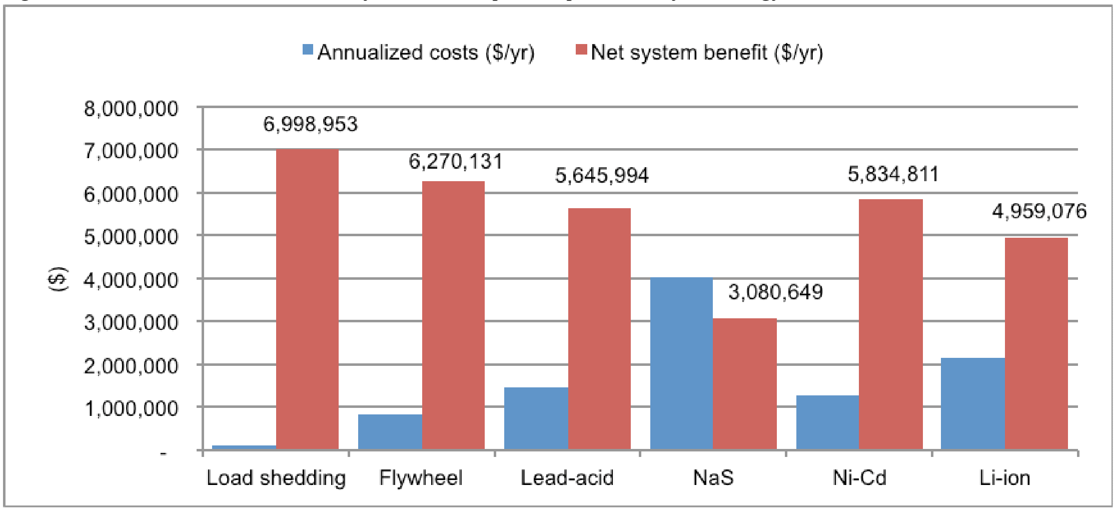


Figure 4-3: The annualized costs and net system benefit specified per reliability technology scenario



5. Discussion

The potential of DSM to facilitate the integration of additional wind energy on the Aruban electricity system has been examined. UC through LP allowed for a quantitative assessment of the systems flexibility. Due to the already high penetration of wind energy in combination with the isolated character of the system one might expect that the integration of an additional wind park would lead to imbalances. The results in this research support and augment these expectations and revealed that imbalances occur at times of sudden and severe wind decreases (between-20 and -25 MW per 10 minutes) in combination with a high utilization of fast spinning reserve capacity.

If the aim is to mitigate all imbalances it is necessary to minimally extend the generation portfolio with a fast reserve that is able to provide 8MW of power, within 10 minutes for at least 7 times a year. Despite these requirements, a cost-effective and technical feasible DSM program exists to maintain balance under such circumstances. By means of literature study and desktop research, the direct load shedding of AC loads in the hotel industry was identified as a suitable DSM solution in this regard.

The simulation tool as presented was able to answer the proposed modelling questions satisfactorily to a large degree. However, not all non-linear unit characteristics constraints could be modelled correctly. These shortcomings resulted in tweaking the model manually and although it is a valid model still some uncertainty exists about the precise quantification of the imbalances.

Furthermore, analysing the costs and benefits showed that the costs for load shedding are lowest, resulting in the scenario with the highest net benefits. The avoided system costs can be allocated as a financial incentive for participants and could be a necessary intervention to overcome associated barriers. Regardless of the financial compensation, the hotel industry tended to be uncertain and reserved about the proposition, mainly due to a lack of information and coordination. To what extent these barriers limit the technical potential of AC load is unclear. The first two barriers are knowledge barriers, where additional information can be provided through pilot studies, metering, testing, etc. The third barrier however, can be partly explained by a lack of information but moreover by the lack of institutional coordination between the intervening utility and the customer. Communication through negotiations or coordination by means of contract and arrangements is advised in this respect. The barriers of access to capital and split incentives did not prove useful in identifying barriers for load shedding. This could be explained by the fact that 1) load shedding does not require large investment and 2) the utility bears these costs.

Generalisation

Although this research was performed for Aruba, the value of this research is not limited to this island. Similar to this case, most SIDS electricity systems are isolated and currently operate no storage, interconnections or DSM programs. In addition, much of the other RETs are similarly dependent on external factors i.e. temperatures, wind speeds, solar intensity, tides resulting in variable output. Despite, the similarities, several results are too case-specific for generalization due to specific unit characteristics, local demand patterns, local wind fluctuations and specific load profiles. However, the methodology can easily be adapted and conceptualized for other SIDS who wish to assess the potential of DSM to facilitate other forms of RETs. It is recommended to further extent this methodology with additional case studies.

6. Conclusions

Through a mixed method research approach it is found that shedding air-conditioning load of the Aruban hotel industry is a technical and economical feasible DSM program in providing sufficient compensating capability for the variable output of an additional wind farm of 30MW. Despite, the potential, implementation may be hampered by customer related barriers and requires further research. It is recommended to overcome these knowledge-based barriers as well as the uncertainty related to the capacity and ramp rates of AC load by providing information through detailed metering studies, testing or pilot studies.

References

1. Hoyle, B., *Islands, transport and development. In: Biagini, E., Hoyle, B. (Eds.),*. Insularity and Development: International Perspectives on Islands. Pinter, London., 1999.
2. United Nations Economic and Social Council, *Sustainable Development of Energy Resources in Small Island Developing States.* E/CN.17/1996/20/Add.2. United Nations, New York, 1996: p. 1-18.
3. Kakazu, *Sustainable Development of Small Island Economies.* Westview Press, Oxford, 1994.
4. Mayer, P.C., *Reliability economies of scale for tropical island electric power.* Energy Economics, 2000. **22**(3): p. 319-330.
5. Farinelli, U., *Energy as a Tool for Sustainable Development.* European Commission and UNDP, New York, 1999.
6. Headley, O., *Renewable energy technologies in the Caribbean.* Solar Energy, 1997. **59**(1-3): p. 1-9.
7. Jensen, T.L., *Renewable Energy on Small Islands.* Forum for Energy and Development, Denmark., 2000.
8. Weisser, D., *On the economics of electricity consumption in small island developing states: a role for renewable energy technologies?* Energy Policy, 2004. **32**(1): p. 127-140.
9. Gellings, C.W., *The concept of demand-side management for electric utilities* Proceedings of the IEEE, 1985. **73**(10): p. 1468-1470.
10. Gellings, C.W., *Integrating demand-side management into utility planning.* IEEE Transactions on Power Systems, 1986. **1**(3): p. 81-87.
11. Bellarmine, G.T., *Load management techniques.* Proceedings of the IEEE, 2000. **10**(1109): p. 139-145.
12. Albadi, M.H. and E.F. El-Saadany, *A summary of demand response in electricity markets.* Electric Power Systems Research, 2008. **78**(11): p. 1989-1996.
13. Kostkova, K., et al., *An introduction to load management.* Electric Power Systems Research, 2013. **95**(0): p. 184-191.
14. Associates, C.R., *Primer on demand-side management with an emphasis on price-responsive programs*, R.P.f.t.W. Bank, Editor 2005: Washington, DC.
15. Bohdanowicz, P., Churie-Kallhauge, A., Martinac, I. *Energy-efficiency and Conservation in Hotels - Towards Suistanable Tourism*. 2001.
16. Escalante, A. *Energy Conservation in the Caribbean - A profitable industry for regional and foreign entrepreneurs*. 2006.
17. Henry, G. *Energizing the Caribbean Hotel Industry*. World Tourism Day, 27th september, 2012 2012 [cited 2013 20 february 2013]; Presentation]. Available from: http://www.onecaribbean.org/content/files/WTD2012GHENRYEnergizingCaribbeanTourismIndustry.pdf.
18. Aho, I., et al., *Optimal load clipping with time of use rates.* International Journal of Electrical Power & Energy Systems, 1998. **20**(4): p. 269-280.
19. Kabouris, J., et al., *Computational environment to investigate wind integration into small autonomous systems.* Renewable Energy, 1999. **18**(1): p. 61-75.
20. Keane, A., et al., *Demand side resource operation on the Irish power system with high wind power penetration.* Energy Policy, 2011. **39**(5): p. 2925-2934.
21. Rosso, A., Ma, J., Kirschen, D.S., Ochoa, L.F.,, *Assessing the contribution of demand side management to power system flexibility*, in *Proceedings of IEEE Conference on*

*Decision and Control and European Control Conferenec 2011*2011: Schotland.

22. Bradley, P., M. Leach, and J. Torriti, *A review of the costs and benefits of demand response for electricity in the UK.* Energy Policy, 2013. **52**(0): p. 312-327.
23. Sundararagavan, S. and E. Baker, *Evaluating energy storage technologies for wind power integration.* Solar Energy, 2012. **86**(9): p. 2707-2717.
24. Poonpun, P. and W. Jewell. *Analysis of the cost per kWh to store electricity*. in *Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE*. 2008.
25. Keay, M., *Renewable energy targets: the importance of system and resource costs.* The Oxford Institute for Energy Studies, 2013.
26. UNIDO, *Barriers to industrial energy efficiency: a literature review*, U.N.I.D.O. (UNIDO), Editor 2011. p. 83.