Using Storage Capacity Rights to Overcome Cost Recovery Hurdles for Energy Storage

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Abstract

or trans ss on r at s serv c s t at ar not pr c n an ar t Inst a t batter s wou b op rat so on t bas s o a n strat v nstruct ons prov b t CAS As suc t batter s wou b op rat n t sa ann r as capac tors t at ar us to a r ss trans ss on ssu s an wou not t r at n t CAS s ar t n pn nc In o n so western Gr x p c t pr c u t poss b t o us n t batter s or an r or AS serv c s as t os serv c s ar pr c n t ar t n t EAS cas t FE RC a ow t cost o t batter s to b rat bas

T a n to t r t s two c s ons ra s so ssu s r ar n cost r cov r or n r stora t at av portant p cat ons or c nt nvest nt n an us o stora Contrast n t c s ons n t EAS an western Gr cas s su sts t at a stora av op r ust a a consc ous c s on o w t r to *only* o r serv c s t at ar not pr c n t ar t or to o r serv c s t at ar pr c I t av op r c oos s t or r t western Gr cas su sts t at nvest nt an ot r costs can b rat bas T s b n c a to t av op r b caus rat bas nvest nts t n to av ow r r s t an ass ts t at ust r cov r costs n a co p t t v ar t

D p o n a stora ass t t at on prov s unpr c serv c s can r su t n n c nt ass t us ow v r As an x a p o t s ta t t batter s propos n t western Gr cas an cons r a a on w c t n r stor n t batter s s not n t or trans ss on r at serv c s B caus t batter s ar not n t or trans ss on r at serv c s an wou t us r a n t cou b b n c a to sc ar t batter s n r or AS pr c s ar su c nt

Do n so wou b b n c a to t batter own r as r ct n t ar t r v nu s t at wou b arn T s us o t batter s a so soc a b n c a as t a ows ow r cost n r t at as a r a b n c ar nto t batter to sp ac r cost n r t at wou ot rw s b us w n t ar t pr c s] How v r to r c v rat bas cost r cov r western Gr x p c t pr c u t poss b t o us n t batter to prov an serv c t at s pr c n t ar t n ts n s T ru n n t EAS cas su sts t at western Gr a not av r c v rat bas cost r cov r w t out t s x p c t st pu at on T s cr at s a c ar op rat ona n c nc as t ass t ust s t w n t cou prov a soc a an pr vat va uab serv c In on o t ob ct ons t at t CAS ra s to rat bas cost r cov r n t western Gr cas s t at t wou orc rat pa rs to cov r t cost o batter s t at wou not b us to t r u pot nt a How v r t s tat on o us n t batter s on or unpr c serv c s was n t to nsur rat bas cost r cov r

T s tat on on captur n ar t pr c va u b stora ass ts prov n unpr c serv c s can a so n r c nt stora nvest nt T s s b caus stora a b a or cost a t rnat v to a trans ss on or str but on capac t up ra w n cons r n capac t t rra *only* How v r a str but stora ass t can prov n r an AS n a t on to capac t t rra t a b a or c ono c so ut on n n t] T western Gr an EAS c s ons su st ow v r t at a str but n r stora s st a not b ab to captur n r an AS r v nu s w a so av n propr rat trеat nt o ts capac t t rra b n ts

Int r st n t nab t o t batter s n t western Gr cas to captur n r an AS r v nu s w r c v n rat bas cost r cov r u t at b ca a n ranc to t pro ct b n p o In ts ru n on t cas t FE RC r qu r t CAS to va ua t t western Gr proposa as an a t rnat v to tra t ona trans ss on up ra s n n w t FE RC r r 890 T CAS t r n t at t western Gr batter s w r not t ost pru nt trans ss on up ra opt on I t batter s cou av prov n r or AS to ra part o t r nvest nt costs t a av b n s ct as t ost pru nt a t rnat v

T a t rnat opt on or a stora av op r s to prov serv c s pr c n t ar t *only* t r b or on rat bas n o t ass t cost I a stora ass t s b n bu t so or pr ar to prov serv c s pr c n t ar t t s can b a v ab opt on A r a wor x a p o t s s or t an 300 o w an batter pro cts v op to prov r qu nc r u at on r s rv s] An portant tat on o t s stora v op nt para ow v r s t at t o s not a ow or stora to prov a co b nat on o serv c s As an x a p a stora ass t a not b co no ca pru nt on t bas s o r qu nc r u at on r v nu s a on How v r t cou captur t va u o trans ss on rra b n ts n a t on to r qu nc r u at on r v nu s t a b a pru nt nvest nt T EAS c s on su sts t at suc co n n o pr c an unpr c s rv c s w not b a ow b t FE RC

T FE RC s c s on not to rat bas t cost o t EAS p ant st s ro a un a nta pr nc pa un r n co p t t v w o sa ctr c t ar t s n T ar t pro uc s pr c s na s t at r v t s st towar an qu br u t at s s ort an on run c nt T r su t n c nc o t ar t s pr s n part on t assu pt on t at ass ts co p t n n t w o sa ar t r cov r t r costs t rou ar t r v nu s I subs s or ot r ar t stor t ons nat t s co p t t v pr ssur t pr c or at on proc ss a not ar t c nc S ar rat bas n t EAS p ant an a ow n t to part c pat n t w o sa ar t can ar pr c or at on

T s ssu o pr c or at on w t a subs stora ass t as a so b n p a n out n t stat o T xas In ov b r 2014 ncor a trans ss on an str but on ut t propos bu n 5 G o str but stora n t stat o T xas T s proposa was bas on an ana s s su st n t at 5 G o stora cou ust ts nvest nt cost t rou t ran o serv c s t at t cou prov]

A qu st on t at was at ra s b t s proposa was w t r stora ass ts own b a r u at trans ss on an str but on ut t w c wou r c v rat bas cost r cov r cou part c pat n t w o sa E RC T ar ts

cf a 12 o t FE RC s r r on t t on or Dic arator r r n t western Gr cas

ar ts t r s no capac t pro uct n E RC T As suc nv rators ust r cov r t r costs so t rou scarc t pr c n n t nv r an A ar tsS tora assts r c v n rat bas cost r cov r part c pat n n t s ar ts cou a p n scarc t pr c s t r at n n utur nv rat on nv st nt

s at on an r u ator ru n s at t t o ncor s proposa pr c u a trans ss on an str but on ut t own n ass ts *e g* nv rat on t at part c pat n t w o sa E RC T ar ts As a r su t ncor as not t proc w t ts proposa Accor n to ncor stora ass ts ar t to prov n vo ta support bac up nv r an str but on capac t rra w c ar stan ar s rv c s prov b trans ss on an str but on ut t s but cannot prov ar t pr c s rv c s suc as nv r arb tra an r qu nc r u at on t r nanc a v ab t s t

III S T RAGE CA ACIT Y AUCT I

S ct on II su sts t at an r u ator an cost r cov r para or nv r stora s ou a sat s t r prop rt s F rst t s ou a ow a stora ass t to captur t va u o *all* o t s rv c s t at t cou pot nt a prov r ar ss o w t r t ar pr c n a co p t t v ar t or not S con t s ou not r on t ar t op rator spatc n t stora ass t n a ann r t at t r at ns ts ar t n p n nc F na t s ou not ntro uc an subs s or ot r stort ons to t pr c or at on proc ss n co p t t v ar ts

ur propos so ut on to t ssu s ra s nS ct on II s to xt n t o propos b H *et al*] to a r at u t p us s o nv r stora T art o our proposa s to ntro uc a ar t t at co p t t v auct ons stora

tor n t ob ct v ax s t va u o nor
n stora assoc at w t t a ocat on o nor capac t
r ts T s s bo b t b s $e_{t,t',m}$ sub tt or
nor capac t r ts

En r ba anc constra nts 3 n t n n our t
S C o t stora v c n tor s o t our $(t-1)$S C an
t our t c ar n an sc ar n a ocat on T c ar n
c nc actor c_s app to nor c ar nto stora
T carr n c nc actor s_s app to t nor
carr ov r ro t pr v ous our

Constra nts t t S C o t stora v c n ac
our bas on t v c s ours o stora capac t T
ow r boun s n t s constra nts ar n b t a ocat on
o nor capac t r ts T s s b caus nor capac t
r ts nt t t o r to stor nor b tw n t n ct on

c s on var ab s n v ctor or an σ− σ+ − + c,− c,+ d,− d,+ e,− an e,+ as t a ran u t p rs n v ctor or

Proposition 1: S uppos q̄c q̄d q̄e s̄ σ̄− σ̄+ − − −+ −c,− −c,+ −d,− −d,+ −e,− an −e,+ sat s KKT con t ons – Cons r t o ow n p f pr c n ru s or stora capac t r ts our t pow r capac t c ar n r ts ar pr c at

$$- \ c \ t - \ c \cdot (\ \bar{t} - \ t^{+})$$

our t pow r capac t sc ar n r ts ar pr c at

$$- \ t - (\ \bar{t} - \ t^{+})$$

an nv r capac t r ts cons st n o an our t n c t on an our t' w t rawa ar pr c at

$$^{c} \ t - \ t' - \sum_{\tau=t}^{t'-1} \sigma_{\tau}^{-} + \ ^{c} \cdot (\ \bar{t} - \ t^{+}) - (\ \bar{t'} - \ t'^{+}).$$

T n t a ocat on o stora r ts (q̄c q̄d q̄e) an t pr c s const tut an qu br u n t s sns t at ac stora r t own r wou want to o ow t n ct ons an w t rawa s sp c b t a ocat on

Proof: Cons r an a nt t at s n pn nt o t stora own r t at wou to n ct up to $Q^{c}_{\tau,i}$ n our at a p f pr c o at ost $^{c}_{\tau,i}$ an w t raw up to $Q^{d}_{\tau',j}$ n our ′ at a p f pr c o at ast $^{d}_{\tau',j}$ T a nt wou t r n ow uc nv r to c ar n our w c w not b $x^{c}_{\tau,i}$ an ow uc to sc ar n our ′ w c w not b $x^{d}_{\tau',j}$ to ax pro t Fo ow n t propos pr c n sc t a nt so v s t pro t ax at on prob

$$\max_{x} \ \left(\ ^{d}_{\tau',j} - \ _{\tau'} - (\ \bar{\tau'} - \ \tau'^{+}) \right) x^{d}_{\tau',j} \qquad (3)$$
$$- \left(\ ^{c}_{\tau,i} - \ ^{c} \ \tau - \ ^{c} \cdot (\ \bar{\tau} - \ \tau^{+}) \right) x^{c}_{\tau,i}$$
$$\text{s t } \ 0 \le x^{c}_{\tau,i} \le Q^{c}_{\tau,i}; \qquad (\ ^{c,-}_{\tau,i} \ ^{c,+}_{\tau,i}) \qquad (3)$$
$$0 \le x^{d}_{\tau',j} \le Q^{d}_{\tau',j}; \qquad (\ ^{d,-}_{\tau',j} \ ^{d,+}_{\tau',j}) \qquad (3)$$

w r t a ran u t p r assoc at w t ac constra nt s n cat n t par nt s s to t r t o t b ct v unct on ax s t va u to t a nt o t n ct on an w t rawa T p f va u o a w t rawa to t a nt s $^{d}_{\tau',j}$ ow v r t a nt ust pa

$$\tau' + (\ \bar{\tau'} - \ \tau'^{+}) \qquad (33)$$

p f w t rawn Conv rs t a nt ncurs a p f cost o $^{c}_{\tau,i}$ or stor n nv r but s pa

$$^{c} \ \tau + \ ^{c} \cdot (\ \bar{\tau} - \ \tau^{+}) \qquad (3)$$

p f n ct T KKT con t ons or t a nt s prob ar

$$^{c}_{\tau,i} - \ ^{c} \ \tau - \ ^{c} \cdot (\ \bar{\tau} - \ \tau^{+}) - \ ^{c,-}_{\tau,i} + \ ^{c,+}_{\tau,i} = 0; \qquad (3)$$
$$- \ ^{d}_{\tau',j} + \ \tau' + \ \bar{\tau'} - \ \tau'^{+} - \ ^{d,-}_{\tau',j} + \ ^{d,+}_{\tau',j} = 0; \qquad (3)$$
$$0 \le q^{c}_{\tau,i} \perp \ ^{c,-}_{\tau,i} \ge 0; \qquad (3)$$
$$q^{c}_{\tau,i} \le Q^{c}_{\tau,i} \perp \ ^{c,+}_{\tau,i} \ge 0; \qquad (3)$$
$$0 \le q^{d}_{\tau',j} \perp \ ^{d,-}_{\tau',n} \ge 0; \qquad (3)$$
$$q^{d}_{\tau',j} \le Q^{d}_{\tau',j} \perp \ ^{d,+}_{\tau',j} \ge 0. \qquad (3)$$

Co par n KKT con t ons (3) – (3) to con t ons (3) (3)

a t ona stora capac t s va uab b caus t a ows or va uab b s or pow r capac t r ts to c ar t auct on As *H* ncr as s ow v r or b s t at ar sub tt or c ar n an sc ar n r ts w t s a r ar ns c ar t auct on an a t ona capac t s ss va uab

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