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REV	DATE	DESCRIZIONE/DESCRIPTION	ESEGUITO/BY	CONTR/CHKD BY	APPROV/APPROV BY

CLIENTE/CLIENT

Enel Green Power S.p.A.

PROGETTO/PROJECT

Impianto di Produzione di Energia da Fonte Eolica in Ambito Portuale - Porto di Genova

TITOLO/TITLE

Progetto Definitivo
Elaborati Impiantistici
Relazione Tecnica Descrittiva degli Impianti

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PROGETTO DEFINITIVO
RELAZIONE TECNICA DESCRITTIVA DEGLI IMPIANTI

1 GENERALITÀ

Il nuovo impianto per la produzione di energia elettrica da fonte eolica, si svilupperà nell'area portuale compresa tra la fiera di Genova e il porto di Genova Voltri (GE). L'impianto sarà costituito da un totale di 39 aerogeneratori, che saranno installati sulle dighe foranee esistenti e poste a protezione delle suddette aree.

L'impianto sarà suddiviso in due aree distinte, una prospiciente al porto di Genova e la seconda al porto di Voltri.

Ciascuno degli aerogeneratori sarà dotato di una cabina di controllo posta sulle dighe in corrispondenza di ciascuna torre.

Tale cabina farà anche funzione di conversione dell'energia in MT 15 kV mediante opportuno trasformatore elevatore con rapporto nominale 0,4/15 kV.

Saranno realizzate due cabine, una per ciascuna area, dove avverrà la consegna dell'energia sulla rete MT 15 kV di proprietà di ENEL Distribuzione. Il collegamento tra la zona di produzione sulle dighe e le cabine di consegna poste a terra, sarà realizzato con cavi per posa sottomarina.

2 DESCRIZIONE DEL PARCO EOLICO

L'impianto sarà costituito da 19 aerogeneratori nell'area di Genova e 20 aerogeneratori nell'area di Voltri, ciascuno della potenza nominale di 199 kW, raggruppati in differenti "cluster" in funzione del tratto di diga su cui saranno installate.

Zona / Cluster	Area /	N° Aerogeneratori	Potenza installata [kW]
1	Genova	8	1592
4	Genova	4	796
6	Genova	7	1393
7	Voltri	4	796
8	Voltri	16	3184

Tabella 2.1: Distribuzione delle potenze installate

Al fine di rispettare i vincoli legati al cono aereo dovuto alla presenza del vicino aeroporto, l'altezza massima degli aerogeneratori (con rotore in posizione verticale) è fissata entro 47,5m rispetto al livello medio delle acque.

2.1 SISTEMA DI CONTROLLO

Il parco eolico verrà controllato, supervisionato e monitorato da remoto. La comunicazione tra SCADA, installato all'interno della cabina di consegna, e le unità PLC delle singole turbine avverrà tramite fibra ottica posata lunga la linea di evacuazione dell'energia.

2.2 SISTEMA DI ALIMENTAZIONE

L'energia elettrica in bassa tensione necessaria per gli ausiliari sarà derivata direttamente dalle strutture del parco. All'interno delle cabine di consegna sarà installato un apposito trasformatore 15/0,4 kV per alimentare il sistema di controllo, di protezione e manutenzione.

L'avviamento dei generatori a parco eolico fermo avverrà tramite alimentazione da rete attraverso la stessa linea MT di evacuazione dell'energia

Non sarà necessaria la fornitura di acqua e gas.

2.3 POSIZIONAMENTO AEROGENERATORI

Il posizionamento degli aerogeneratori è stato stabilito sulla base dei seguenti criteri:

- Rispetto della distanza minima suggerita dal costruttore degli aerogeneratori.
- Rispetto del cono aereo legato alla presenza del vicino aeroporto
- Struttura della diga foranea. L'installazione delle macchine tiene conto delle differenti caratteristiche della diga nei diversi tratti individuati per l'installazione delle macchine

La zona dove è previsto il parco eolico è stata caratterizzata dal punto di vista anemologico in via preliminare. E' prevista una approfondita campagna di misure triennale, con lo scopo di determinare in modo accurato:

- velocità del vento
- direzione predominante del vento
- Potenziale eolico
- posizionamento definitivo degli aerogeneratori

L'acquisizione dei dati sarà effettuata mediante due stazioni di rilievo anemometrico, che saranno collocate, la prima sulla diga foranea di Genova, la seconda sul tratto nuovo di Voltri.

2.4 PROTEZIONE DALLE SCARICHE ATMOSFERICHE

La protezione dalle scariche atmosferiche sarà garantita dalle torri metalliche degli aerogeneratori che saranno connesse in più punti al dispersore di terra localizzato alla base delle stesse

2.5 RETE DI TERRA

L'impianto di terra avrà la funzione di:

- Ridurre il potenziale elettrico delle superfici metalliche a valori ammissibili, evitando il pericolo di folgorazione a seguito di anomalie, guasti e tensioni indotte.
- Disperdere le sovratensioni di origine atmosferica
- Fornire un unico riferimento di tensione per tutto il parco eolico.

Saranno collegati all'impianto di terra tutti i seguenti elementi:

- Supporti metallici
- Armature del calcestruzzo
- Parti metalliche degli aerogeneratori
- Schermi e armature dei cavi
- Cassa delle macchine elettriche
- Neutro dei trasformatori MT/BT
- Trasformatori di misura
- Sezionatori di terra

In corrispondenza di ciascun aerogeneratore, e della relativa cabina di trasformazione sarà realizzata una maglia di terra annegata nel calcestruzzo che funzionerà da collettore locale e che sarà collegato alle calate in mare e agli altri dispersori attigui mediante appositi cavi in rame. L'impianto di terra realizzato sulla diga dovrà essere collegato, mediante cavi idonei alla posa sottomarina, al dispersore posto a protezione della cabina MT di consegna.

3 CARATTERISTICHE TECNICHE

Per gli schemi unifilari dell'impianto si faccia riferimento ai documenti:

n° 12-412-PD_D_005 "Schema elettrico unifilare Zona GENOVA"
n° 12-412-PD_D_006 "Schema elettrico unifilare Zona VOLTRI"

Di seguito vengono descritte le caratteristiche dei componenti principali:

3.1 CONDIZIONI DI FUNZIONAMENTO

Diametro del rotore:	30 m
Velocità del vento (cut-in):	3,5 m/s
Velocità nominale del vento:	11 m/s
Velocità del vento (cut-off):	25 m/s (36 m/s istantanea)

E' previsto l'arresto delle macchine qualora l'intensità del moto ondoso sia tale da interferire con la rotazione delle pale (superamento "splash-zone").

3.2 GENERATORE

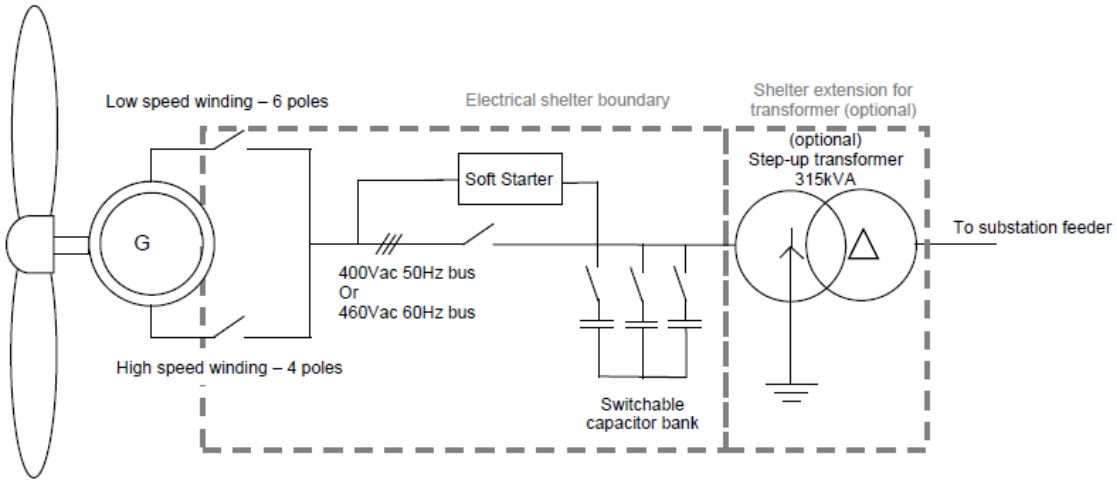
Il generatore è costituito da una macchina asincrona a 2 velocità, con rotore a gabbia di scoiattolo.

Potenza nominale:	199 kW
Tensione nominale:	400 V @ 50 Hz
Fattore di potenza:	0,85
Contributo alla Icc trifase massima (Ik"):	3,76 kA (ai morsetti)
Avviamento e sincronizzazione:	Soft Starter

3.3 QUADRO LOCALE DI CONTROLLO AEROGENERATORE

Le cabine alla base di ciascun aerogeneratore ospiteranno i seguenti componenti:

- PLC di controllo turbina
- Interruttore di macchina
- Soft Starter
- Gruppo di rifasamento
- trasformatore elevatore 0,4/15 kV
- Quadro di sezionamento MT



Le cabine saranno collegate con cavo MT 15 kV, in configurazione entra esci. La connessione tra l'ultima cabina del cluster sulla diga e la banchina portuale sarà eseguito con cavo idoneo alla posa sottomarina.

3.4 TRASFORMATORE ELEVATORE

Potenza nominale:	315 kVA
Tensione nominale primario:	0,400 kV
Tensione nominale secondario:	15 kV
Frequenza:	50 Hz
Messa a terra lato BT:	neutro francamente a terra
Raffreddamento	ONAN
Connessione:	Dyn11
Tensione di corto circuito:	4%
Tap changer (lato MT):	5%
Inrush current peak Ie/In:	12

4 ASSETTI DI FUNZIONAMENTO

Il parco eolico è progettato per le seguenti condizioni di funzionamento:

4.1 STAND-BY

Il parco eolico è in condizioni di fermo produzione. Nessuno degli aerogeneratori è in produzione. Gli interruttori BT di macchina sono aperti.

L'energia per il mantenimento dei sistemi ausiliari e di controllo viene prelevata dal punto di consegna.

4.2 AVVIAMENTO

Con impianto in stand-by e trasformatori elevatori in funzionamento a vuoto, vengono chiusi gli interruttori di macchina corrispondenti agli aerogeneratori da avviare. La macchina asincrona viene alimentata attraverso avviatore SOFT STARTER, fino all'esaurimento del transitorio. L'energia necessaria per l'avviamento viene prelevata dal punto di consegna.

Qualora l'impianto non fosse in stand-by è possibile prelevare l'energia in toto o in parte dagli altri generatori in funzione

E' previsto l'avviamento di un solo cluster alla volta all'interno della stessa area (punto di consegna)

Nella seguente tabella sono riportati i dati di potenza assorbita nel transitorio di avviamento, forniti dal costruttore:

	Averaging time (sec)	Active power (kW)	Ratio to nominal power	Reactive power (kVAR inductive)
Maximum measured power $P_{0.2}$	0.2	421	1.53	86
Maximum measured power P_{60}	60.0	279	1.01	4
Maximum measured power P_{600}	600.0	273	0.99	1

Tabella 4.1: Dati di potenza assorbita nel transitorio di avviamento

4.3 FUNZIONAMENTO NORMALE

Il parco eolico eroga potenza verso la rete. Nessun transitorio di avviamento o di fermata è in corso. L'impianto è progettato per funzionare con tutti gli aerogeneratori in produzione alla potenza nominale.

4.4 EMERGENZA

In caso di anomalie/mancanza di collegamento con la rete, l'alimentazione dei PLC di turbina è garantito da gruppi UPS installati nelle cabine ai piedi di ciascun aerogeneratore, fino all'arresto/messa in sicurezza dell'impianto. Idonei gruppi UPS saranno installati nelle cabine di consegna al fine di mantenere le alimentazioni essenziali (ausiliari quadri/SCADA)

5 CONNESSIONE ALLA RETE MT – ENEL DISTRIBUZIONE

5.1 POSIZIONAMENTO CABINE DI CONSEGNA

La posizione delle cabine di consegna è stato individuato come di seguito indicato:

- **Zona di Genova**. La cabina è prevista nell'area attualmente occupata dalla centrale ENEL all'interno dell'area portuale e che verrà dimessa e completamente smantellata entro il 2017.
- **Zona di Voltri**: La cabina sarà realizzata nell'area, attualmente in concessione a IREN, attigua all'impianto di depurazione.

Ciascuna cabina sarà equipaggiata con quadro di media tensione e un numero di stalli adeguato al numero dei cluster da connettere. Un apposito scomparto sarà previsto per collegare il trasformatore ausiliario.

Il dispositivo di interfaccia sarà adeguato per soddisfare la normativa CEI 0-16 per la connessione di utenti attivi, il codice di rete TERNA e il recente allegato A70 "Regolazione tecnica dei requisiti di sistema della generazione distribuita"

5.2 SCHEMA DI COLLEGAMENTO ALLA RETE MT

Con riferimento alla norma CEI 0-16, il collegamento con ENEL Distribuzione sarà eseguito in modalità entra-esci su cavo MT esistente, in condivisione con altri utenti passivi già esistenti.

Le nuove cabine si consegna saranno conformi alla norma CEI 0-16.

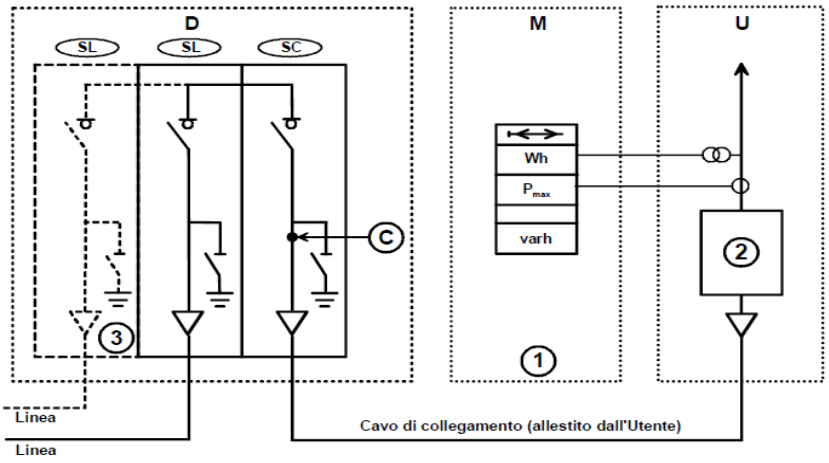


Figura 5.1: Schema di collegamento fra la cabina consegna e impianto di utente attivo

6 RIFERIMENTI

6.1 ALLEGATO 1 - IC-12-GE-FE-001-EN_GENERAL DATA SHEET

6.2 ALLEGATO 2 - IC-10-LV-EL-003-EN_ELECTRICAL SHELTER

6.3 ALLEGATO 3 - IC-10-LV-EL-011-EN_STEP-UP TRANSFORMER

6.4 ALLEGATO 4 - IC-10-LV-EL-010-EN_POWER QUALITY & ELECTRICAL CHARACTERISTICS

Allegato 1 - IC-12-GE-FE-001-EN_General data sheet

General data sheet

GEV MP-R
All sub models



(standard hub height 32.3m)

BLADES (2)

Material	Glass Fiber Composit
Weight	600 or 750kg / blade (1,323 or 1,653lb)
Length	14.65 or 15.65m (48' or 51') each blade
Manufacturer	*AeroComposit Occitane*

NACELLE

Material of external envelope	Glass Fiber Composit
Material	Steel
Weight (with hub)	9.1 t
Manufacturer	*Vergnet SA*

TOWER

Type	Tubular
Material	Galvanized steel ISO 1461
Corrosion protection	Optional painting on galvanization
Weight	12 t (standard hub height 32.3m = 106') 28.7 t (optional hub height 52.3m = 172')
Dimensions	31m (3 x 11m) - (102' = 3 x 36') ø max= 2.25m (7' 5") (standard hub height 32.3m = 106') 51m (5 x 11m) – (167' = 5 x 56') ø max= 2m (6' 7") (optional hub height 52.3m = 172')
Manufacturer	*PETITJEAN or equivalent*

CONTROLS

Type	PLC
Model	S7
Manufacturer	*Siemens*

ACTUATION

Type	Hydraulic pitch, yaw, brake
Manufacturer	*Hydac*

ROTOR

Material	SG Cast Iron
Weight (with blades)	1.9t
Diameter	32m (105') or 30m (98')
Swept area	804.25 m² (8,657 sq.ft) or 706.86 m² (7,608 sq.ft)
Manufacturer	*Vergnet SA*



GENERATOR

Type	Asynchronous, 200 to 275kW Two Speed
Weight	1.1 t
Voltage	400V 50 Hz or 460V 60 Hz
Manufacturer	*ABB or equivalent*

GEARBOX

Type	Planetary with rectified teeth
Weight	1.2 t
Stages	2
Manufacturer	*DINAMIC OIL or BONFIGLIOLI or equivalent*

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allegato 2 - IC-10-LV-EL-003-EN_Electrical shelter

1 FUNCTIONS

The electrical shelter is a LV cabinet installed close to the tower base of each GEV MP wind turbine generator. It contains the main electrical components of the GEV MP.

2 CHARACTERISTICS

Figure 1 - Schematic

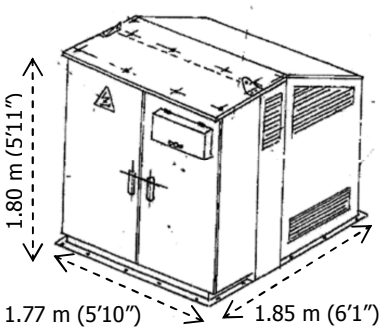


Figure 2 - Front view



Electrical shelter

Figure 3 - Rear view



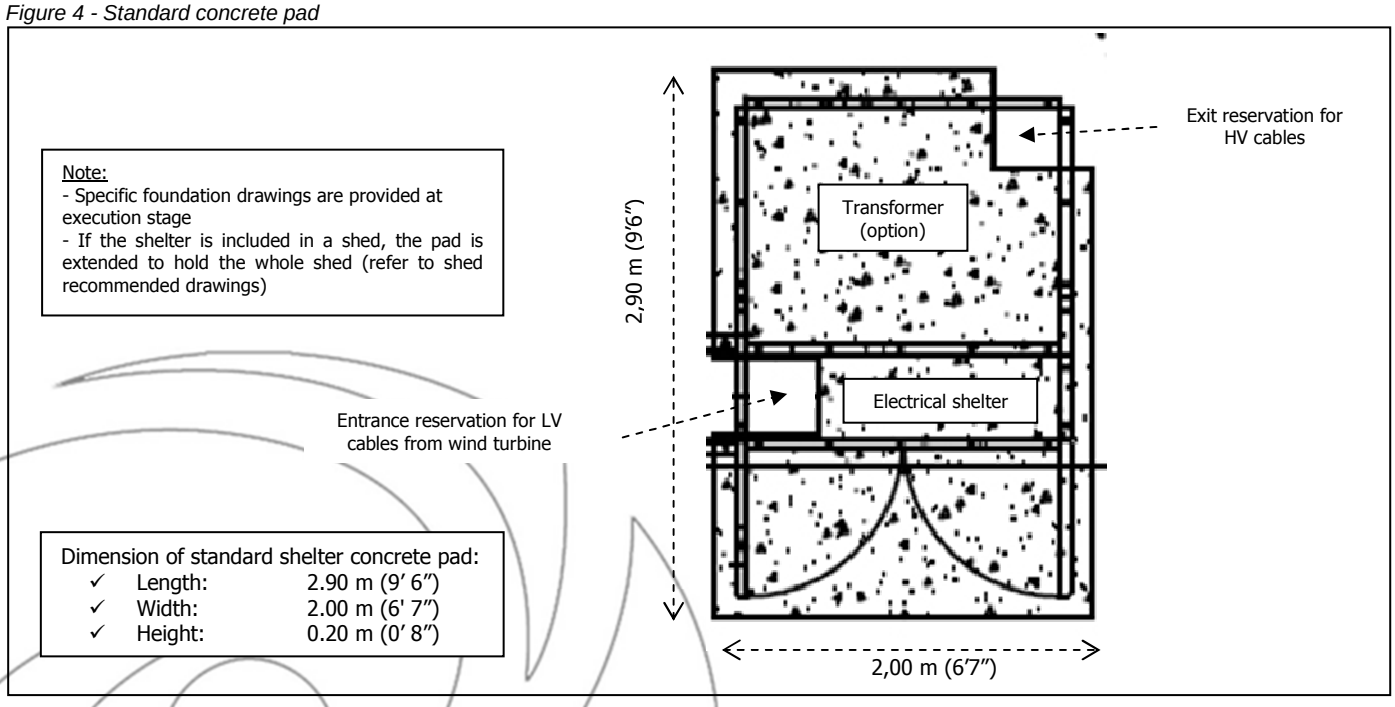
Transformer along LV cabinet on shelter concrete pad, before end of transformer cover assembly



Step-up transformer cover

Weight (without step-up transformer): **473 kg (1,040 lb)**
Color: **Silver**
Envelope: **4mm (1/8") corrosion-resistant marine aluminum**

Figure 4 - Standard concrete pad



Other design characteristics:

- ✓ IP class: 44
- ✓ Marine environment resistant: distance from sea shore < 100m
- ✓ Relative humidity: 100 % (anti-condensation system)
- ✓ UV resistant
- ✓ Anti-seismic construction

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3 INSTALLED DEVICES

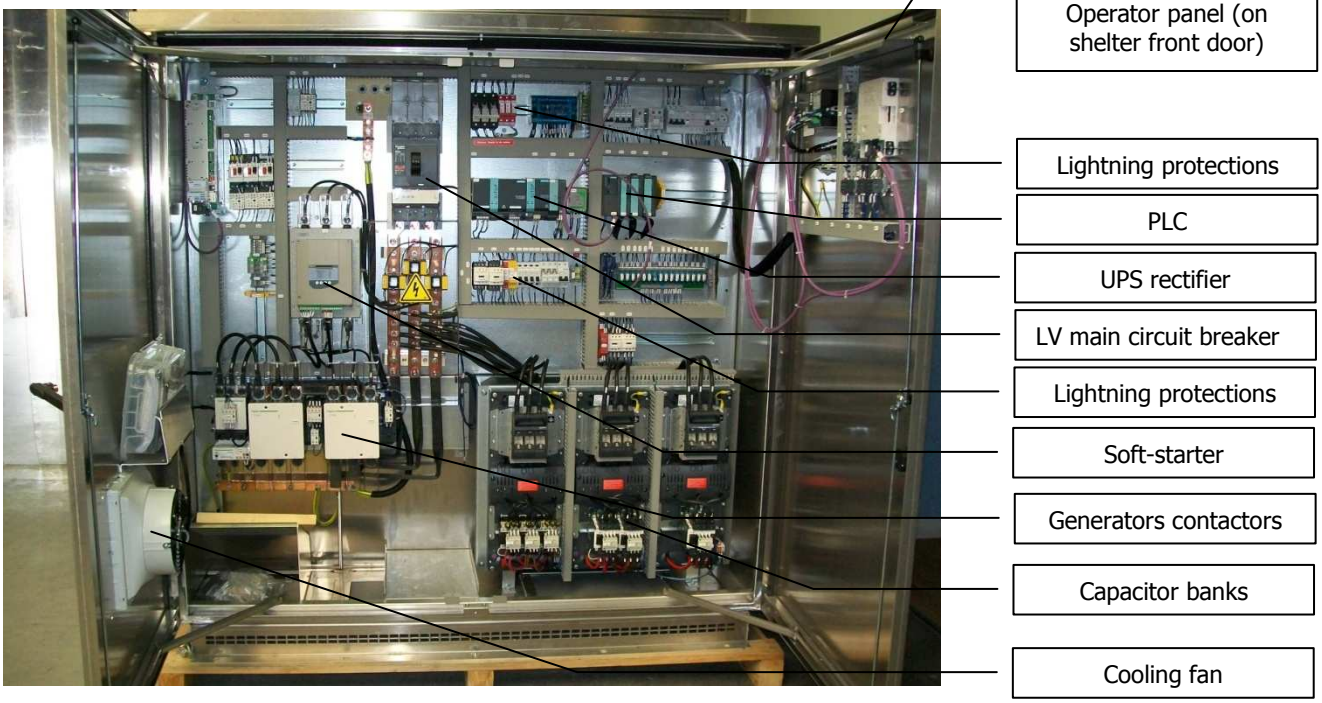


Figure 5 - Inside view of Electrical shelter (LV side)

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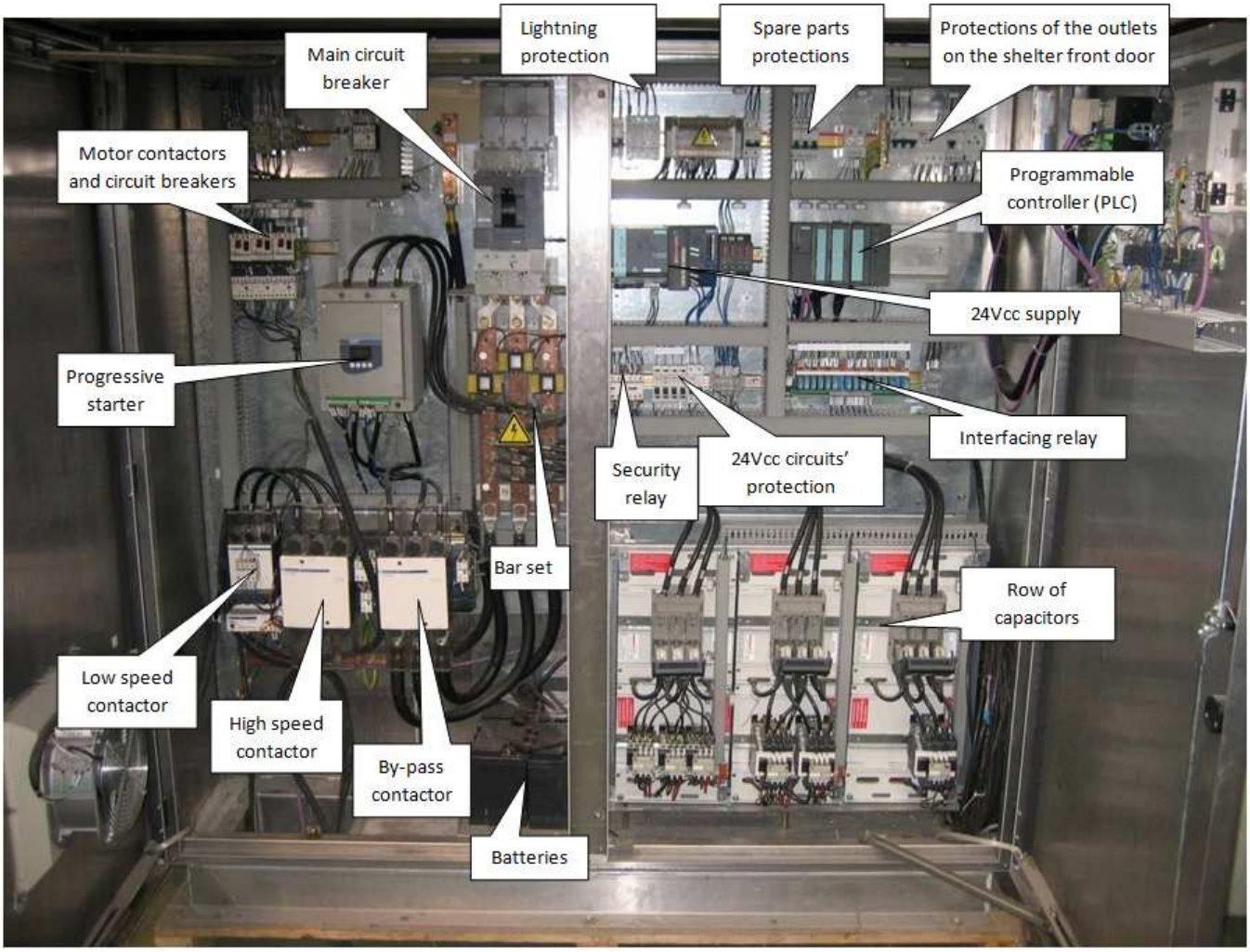


Figure 6 - Inside view of Electrical shelter (LV side)

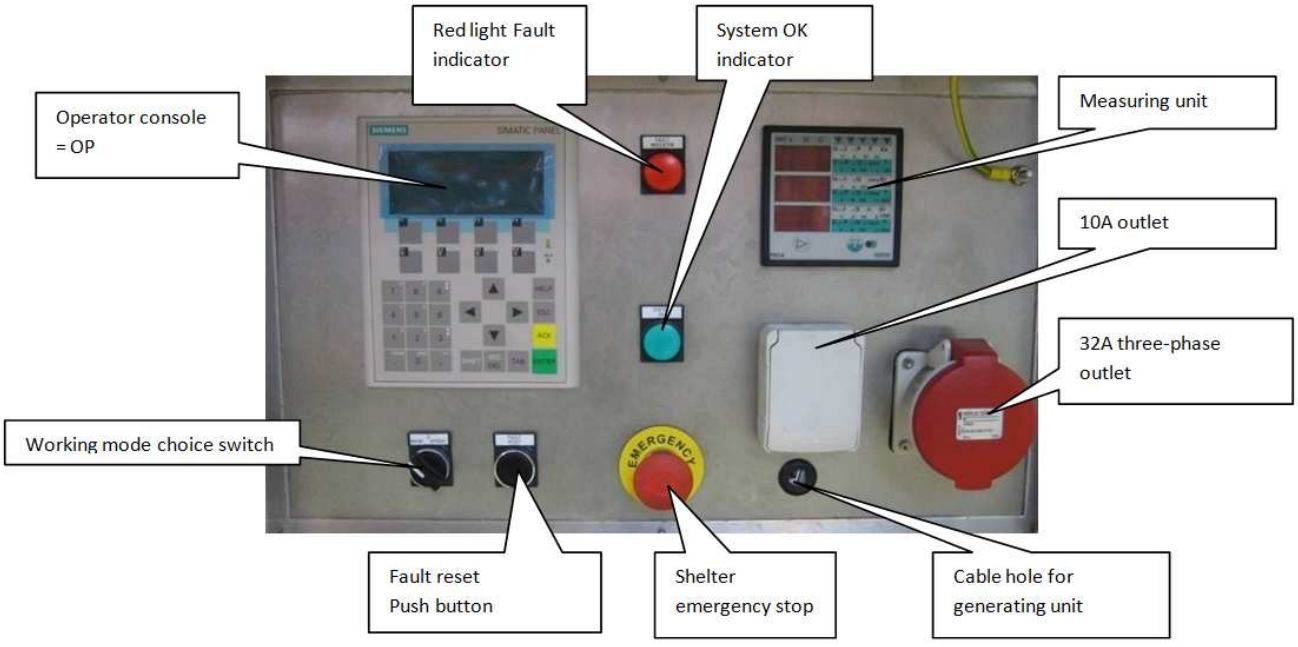


Figure 7 - Operator panel on shelter front door

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4 Electrical shelter model variations

A GEV MP shelter can be completely described by its "E" code describing the electrical shelter and its associated step-up transformer:

E-SHELTER

E RHE ❶ -E1100A ❷ / M A E B F C X D X E X F

❶ Electrical Shelter Descriptor as per Table 1

❷ Options descriptor as per Table 2

4.1 Models

		Code	Default	MP-C	MP-R	Comments
Shelter type ❶	MPC LV 50 Hz shelter (SPE 158)	CLE		•		No electrical grid protection in shelter
	MPC HV 50 Hz shelter (SPE 157)	CHE	•	•		
	MPC HV 60 Hz shelter (SPE 159)	CHU		•		
	MPR LV 50 Hz shelter (SPE 175)	RLE			•	
	MPR HV 50 Hz shelter (SPE 176)	RHE	•		•	
	MPR HV 60 Hz shelter (SPE 177)	RHU			•	
Output Voltage / Frequency ❷	50 Hz 400 V	E0040X	•	•	•	Direct LV output
	60 Hz 460 V	U0046X		•	•	Direct LV output
	50 Hz 400 / 5.5 kV 315 kVA	E0550A		•	•	W/ step-up transformer
	50 Hz 400 / 11 kV 315 kVA	E1100A		•	•	
	50 Hz 400 / 15 kV 315 kVA	E1500A		•	•	
	50 Hz 400 / 20 kV 250 kVA	E2000B		•	•	
	50 Hz 400 / 20 kV 315 kVA	E2000A		•	•	
	50 Hz 400 / 23 kV 315 kVA	E2300A		•	•	
	50 Hz 400 / 33 kV 250 kVA	E3300B		•	•	
	50 Hz 400 / 33 kV 315 kVA	E3300A		•	•	
	60 Hz 460 / 6.6 kV 315 kVA	U0660A		•	•	
	60 Hz 460 / 11 kV 315 kVA	U1100A		•	•	
	60 Hz 460 / 12 kV 315 kVA	U1200A		•	•	
	Others [1]	xxxxxxx		•	•	

Table 1 - Electrical shelter model description

Note:

[1] Development to be quoted on time & material basis.

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4.2 Options

		Code	MP-C	MP-R	Comments
Metering A	Contractual Metering [1]	M / X	•	•	Applicable to CLE or RLE shelters only. Contractual metering in shelter for LV connection. Requires a shelter extension or building.
Electrical protections B	Customized electrical grid protections [1]	E / X	•	•	Applicable to CLE or RLE shelters only. Protection settings require an electrical stability study. Requires a shelter extension or building.
LV Auxiliary Feeder C	LV auxiliary feeder to sub-station	F / X	•	•	Only for CHE, CHU, RHE and RHU shelters to save a auxiliary transformer. Auxiliary 32Amps LV feeder to substation
Disconnector switch D	Disconnector switch on shelter exit	S / X	•	•	Standard is a disconnector, and not a disconnector switch. Applicable to CLE and RLE shelters only.
Building E	Pre-fabricated concrete building	B / X	•	•	Shelter to be installed within building. Compulsory for "Continental" and "Polar" areas. May be necessary for LV connection (if no shelter extension) to install Metering A, Electrical protections B and optional SCADA.
Shelter extension F	Marine aluminum Extension cabinet for LV options	C / X	•	•	May be necessary for LV connection (if no prefabricated concrete building) to install Metering A, Electrical protections B, Disconnector switch D and optional Proxwind SCADA.

Table 2 - Electrical shelter options

Note:

[1] Defined case by case as per Distribution Network Operator (DNO) requirements. Development to be quoted on time & material basis.



Figure 8 - Optional shelter extension F with LV grid protection relay B



Figure 9 - Shelter integrated inside optional concrete building E

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allegato 3 - IC-10-LV-EL-011-EN_Step-up transformer

1. FUNCTIONS

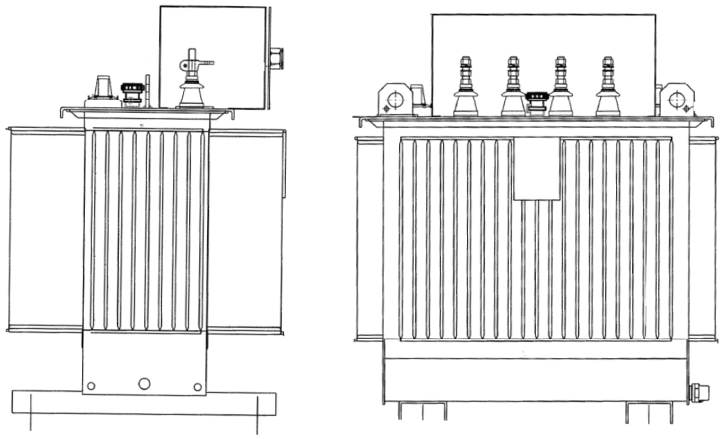
The wind turbine step up transformer converts LV power from the wind turbine generator into HV power to be transported and injected into the electrical grid.

2. GENERAL CHARACTERISTICS

Type :	ONAN (oil-immersed transformer)
Climatic conditions	Temperature -20°C to +40°C (-4°F to 104°F) Humidity 95% Salty atmosphere (sea < 200 m)

Indicative figures for a E02031A transformer:

Weight	1.14 Tons (2500 lbs)
Dimensions LxWxH	1100x885x975 (3.6'x2.9'x3.2')



Outline drawing



Transformers E02031A

3. MODELS

Primary/secondary voltage	Rated power	Frequency	Code	GEV MP-C	GEV MP-R
400V / 5.5kV	315kVA	50Hz	E00631A	●	●
400V / 11kV	315kVA	50Hz	E01131A	●	●
400V / 15kV	315kVA	50Hz	E01531A	●	●
400V / 20kV	250kVA	50Hz	E02025A	● [1]	● [1]
400V / 20kV	315kVA	50Hz	E02031A	●	●
400V / 23kV	315kVA	50Hz	E02325A	●	●
400V / 33kV	250kVA	50Hz	E03325A	● [1]	● [1]
400V / 33kV	315kVA	50Hz	E03331A	●	●
460V / 6.6kV	315kVA	60Hz	U60731B	●	●
460V / 11kV	315kVA	60Hz	U61131B	●	●
460V / 12kV	315kVA	60Hz	U61231B	●	●
Others [2]			Txxxxxx	●	●

Notes:

[1] Wind turbine with rated power S≤250kVA.

[2] Upon request. To be quoted on time & material basis.

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4. ELECTRICAL CHARACTERISTICS

Rated primary voltage:.....400 or 460Vac (see § 3)
Rated secondary voltage: ..... <34.5kVac (see § 3)
Vector group: Dyn11
Short circuit voltage Ucc: 4%
Inrush current peak Ie/In: 12
Admissible deviations

- Frequency
  - Permanent: ..... +/-5%
  - Short term: ..... +/-10% (5 sec)
- Voltage
  - Permanent: .....+/-10%
  - Short term: ..... +/-20% (1.5 sec)

LV Earth system: .....Neutral to earth
Medium voltage protection: .....ensured by feeder protection
Insulation level: ..... 24 or 36kV
Off-circuit tap changer (Medium voltage side): ..... ± 2,5%, ± 5% [1]
Type of cooling: .....ONAN
Isolating: ..... Mineral oil
Monitoring: ..... no sensors needed according to IEC
Short-circuit withstand capability: .....Against external short-circuit during short-circuit periods according to IEC
Interlocking system for safety access: ..... Yes
Manufacturer: ..... PAUWELS or equivalent
Country of origin: ..... Europe

Note:
[1] Specific step-up transformer configuration can be arranged upon request

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allegato 4 - IC-10-LV-EL-010-EN_Power Quality & Electrical Characteristics

GEV MP – Power Quality & Electrical Characteristics
Document # IC-10-LV-EL-010-EN

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1 PURPOSE OF THE DOCUMENT

The present document aims to present the electrical characteristics of the GEV MP wind turbine (WT) in steady state mode as well as in transient modes of operation. The data given herein primarily rely upon the results of the DEWI test report of 2004. Those tests were performed according to IEC 61400 and Measnet codes.

2 DATA SOURCES

[S1] DEWI test report no. 04 0101 dated 22/04/2004
[S2] VSA test report Gommerville dated May 2011

3 REFERENCES

[R1] Standard IEC 61400-21 "Measurement and assessment of power quality characteristics of grid connected wind turbines", edited by IEC
[R2] Standard NF C 13 100 "Postes de livraison établis à l'intérieur d'un bâtiment et alimentés par un réseau de distribution publique HTA (jusqu'à 33 kV)", edited by AFNOR
[R3] Standard NF C 13 200 "Installations électriques à haute tension", edited by AFNOR
[R4] Standard NF C 15 100 "Installations basse tension", edited by AFNOR

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4 WIND FARM MV ELECTRICAL SYSTEM

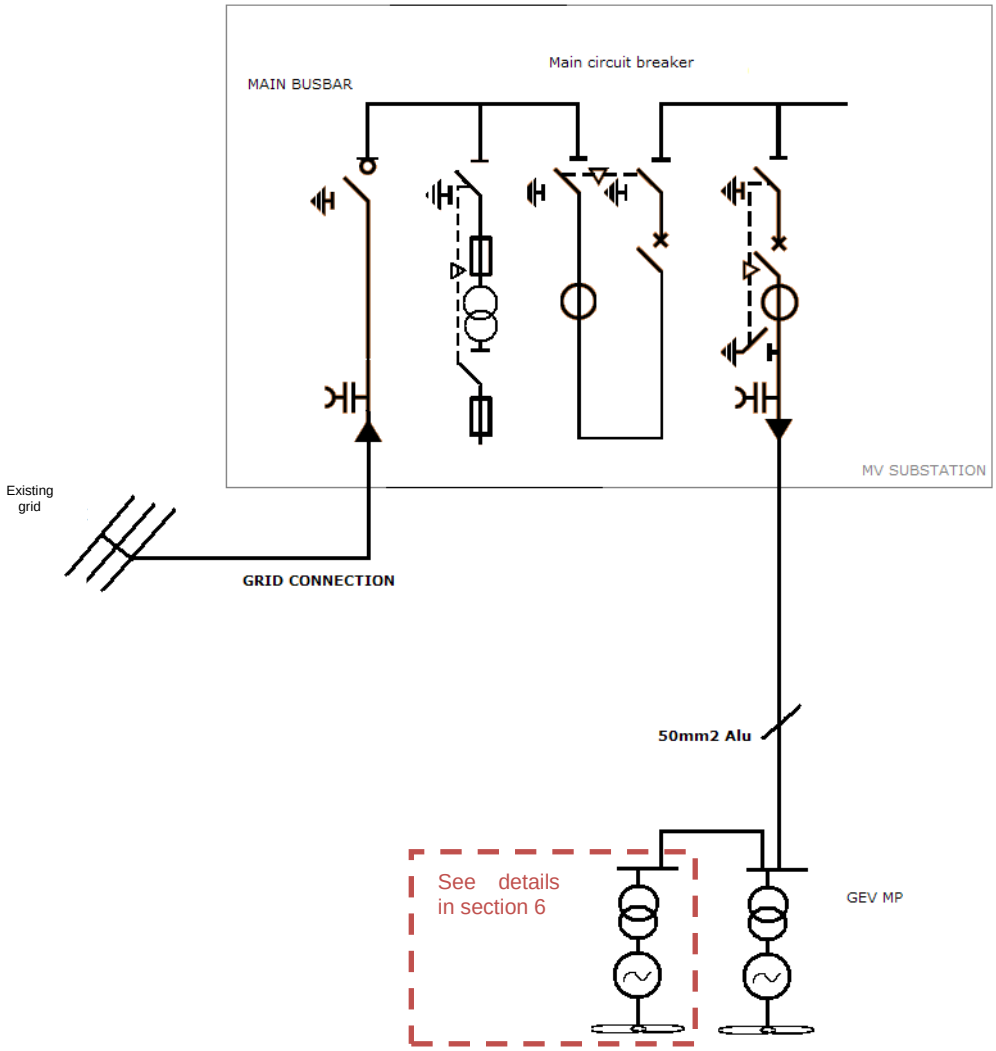


Figure 1 - Wind farm typical single line diagram

Standard characteristics of MV layout	
MV voltage	Standard : 15, 20 or 33kV [1]
Frequency	50 or 60 Hz
Power measurement cabinet	In substation
Electrical protections in substation	50N/51N Neutral Over current 50/51 Phase Over current
Grid protection	27/27S Under voltage 59 Over voltage 81L Under frequency 81R RoCoF 78 Vector shift
Compliances	NF C 13 100 [R2] NF C 13 200 [R3] NF C 15 100 [R4]

Note:

[1] Specific voltages upon demand

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5 WT ELECTRICAL SYSTEM

5.1 Single line schematic

The GEV MP benefits from a rugged but state-of-the-art technology designed for optimum electrical performances:

- asynchronous 2 speeds generator for high availability
- soft starter to limit the voltage dips when connecting the generator to the grid
- switchable capacitor bank to correct over its whole working range the reactive power required by asynchronous machine
- step-up transformer to elevate the voltage to feeder requirements

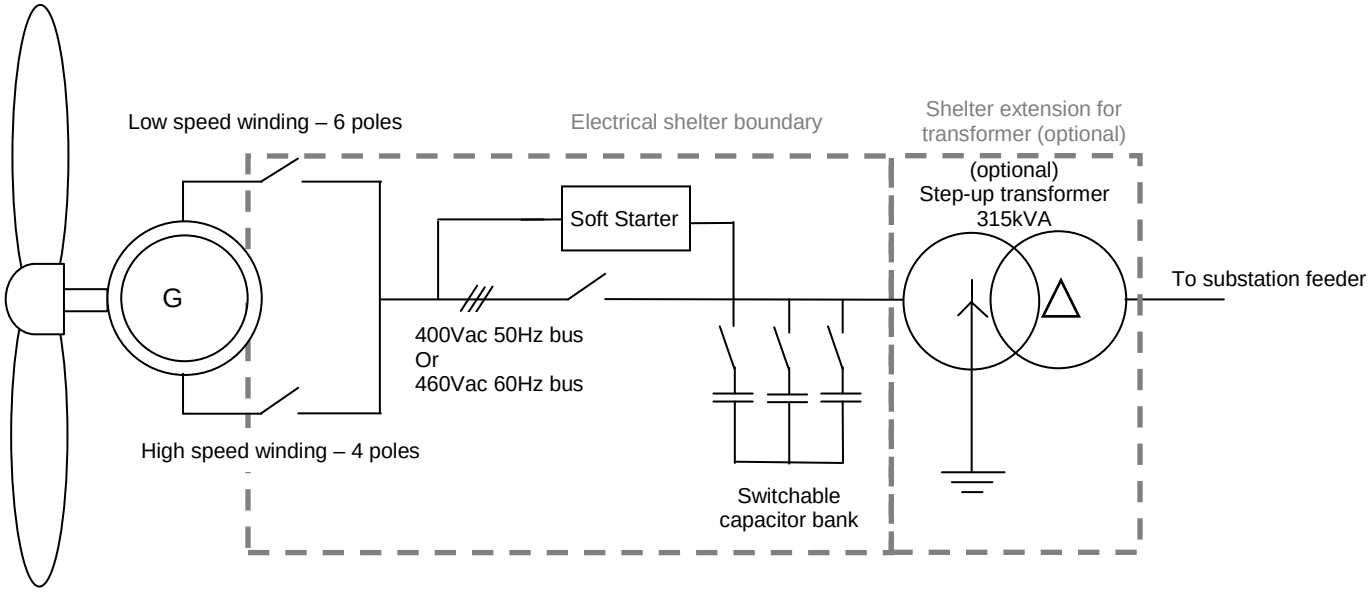


Figure 2 – Simplified WT single line (detail of previous figures)

5.2 Generator description

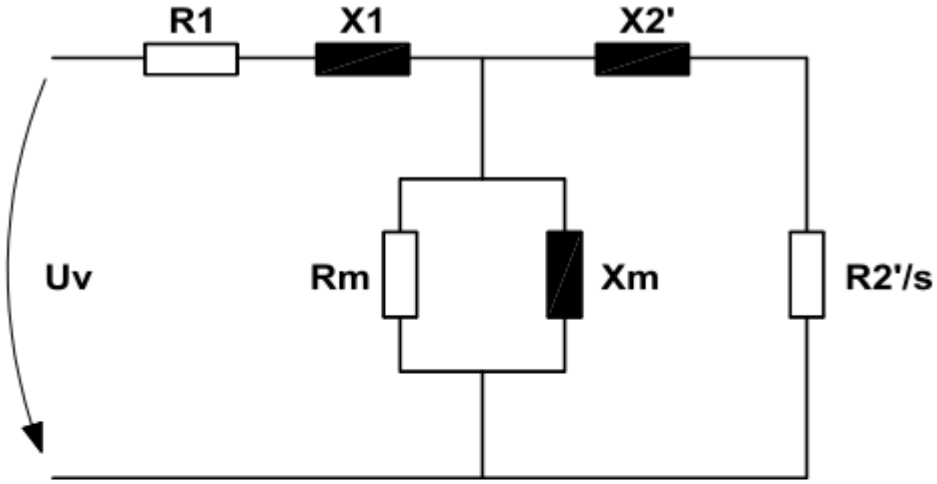
Generator	50Hz	60Hz
Type	asynchronous	
Manufacturer	ABB or equivalent	
Country of origin	Europe	
Rated power (kW)	275 / 75	
Rated voltage	400 V	460 V
Number of poles	4 / 6	4 / 6
Rotor speed	1 512 / 1 008 rpm	1 811 / 1 207 rpm
Rated current	467 / 150 A	411 / 133 A
Efficiency	95.6 % / 92.3 %	95.8 % / 92.4 %
Power factor	0.85 / 0.72	0.84 / 0.71
Rated torque	1 815 / 770 Nm	1 515 / 641 Nm
Short circuit test current	3 415 / 1 110 A	3 082 / 1 130 A
Fault Ride Through	[1]	[1]

Note:

[1] To be specified to comply with grid code

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5.3 Generator single phase equivalent electrical circuit



NOMINAL LOAD		4-pole	6-pole
STATOR RESISTANCE	R1:	6.5	52.0 mΩ
STATOR REACTANCE	X1:	40.5	79.9 mΩ
ROTOR RESISTANCE	R2':	4.4	14.9 mΩ
ROTOR REACTANCE	X2':	73.7	290 mΩ
LOSS RESISTANCE	Rm:	54.8	144 Ω
MAGNETIZING REACTANCE	Xm:	1.46	2.90 Ω
VOLTAGE	Uv:	231	231 V

RESISTANCE VALUES ARE VALID FOR NOMINAL DUTY AND CORRESPONDING TEMPERATURE.

5.4 Capacitor bank description

Capacitor bank	50Hz	60Hz
Type	Switchable by controlled breakers	
Manufacturer	SCHNEIDER ELECTRIC or equivalent	
Country of origin	France	
Rated voltage	400 V	460 V
Full rated reactive power	170 kVAR capacitive	180 kVAR capacitive
Switchable modules	2x 15kVAR 1x 20kVAR 2x 30kVAR 1x 60kVAR	3x20kVAR 2x30kVAR 1x60kVAR

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5.5 Step-up transformer description

Step-up transformer	60Hz		50Hz	
	15kV	20kV	15kV	20kV
Type of transformer	oil immersed & natural convective air cooling			
Manufacturer	PAUWELS, DURIEZ or equivalent		PAUWELS, TRANSFIX or equivalent	
Country of origin	Europe		Europe	
Primary rated voltage	460 V		400 V	
Coupling	Dyn11			
LV earthing system	Neutral to earth			
MV electrical protections	Relies on substation feeder / Grid hardware protection			
Type of cooling	ONAN			
Type of isolating medium	Mineral oil			
Breakdown voltage	24 kV			
Peak inrush current ratio Ie/In	12			
Locking system	Yes			
Working frequency	60Hz ±		50Hz ±	
Secondary rated voltage	15 kV ±	20 kV ±	15 kV	20 kV
Short circuit current Ucc	4%			
Rated frequency				
Monitoring	No monitoring (IEC compliant)			
Short circuit withstanding capability	IEC compliant			
Offline tap changer (MV side)	±2.5% and ±5% as standard [2]			

Note :

[1] Specific step-up transformer configuration can be arranged upon request.

6 SOURCES OF DATA

The WT characteristics presented in the following chapters rely mainly on the measures performed by DEWI in 2004 [S1]. Those measurements were performed in accordance to IEC 61400-21 standard and to Measnet Power Quality Procedure. All measurements were taken at generator terminals.

7 ELECTRICAL CHARACTERISTICS – WT IN STANDBY MODE

This section relates to operating conditions when the wind turbine (WT) is importing active power, typically when it is not generating. This excludes all electrical consumption from the substation if any (ie substation auxiliaries, step-up transformer …).

Maximum active power import	2 kW
Maximum reactive power import	0 kVAr (capacitor bank active)
Maximum reactive power export	22.5 kVAR capacitive

Table 1 - Standby power figures

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8 ELECTRICAL CHARACTERISTICS – WT IN PRODUCTION

8.1 Power factor vs active power

Due to its switchable capacitor bank, the GEV MP allows a power factor tracking close to 1 over its whole power range.

DEWI 2004 [S1] measurement campaign (red line in Figure 3) produced results that were very close to 1 on the higher operating range.
VERGNET SA May 2011 [S2] measurement campaign (blue line) showed the enhancement introduces mainly by optimization of the control of the capacitor bank. Due to these optimizations, even in the lower operating ranges the reactive power profile remain neutral. Third party's confirmation of VSA's measurements are to come.

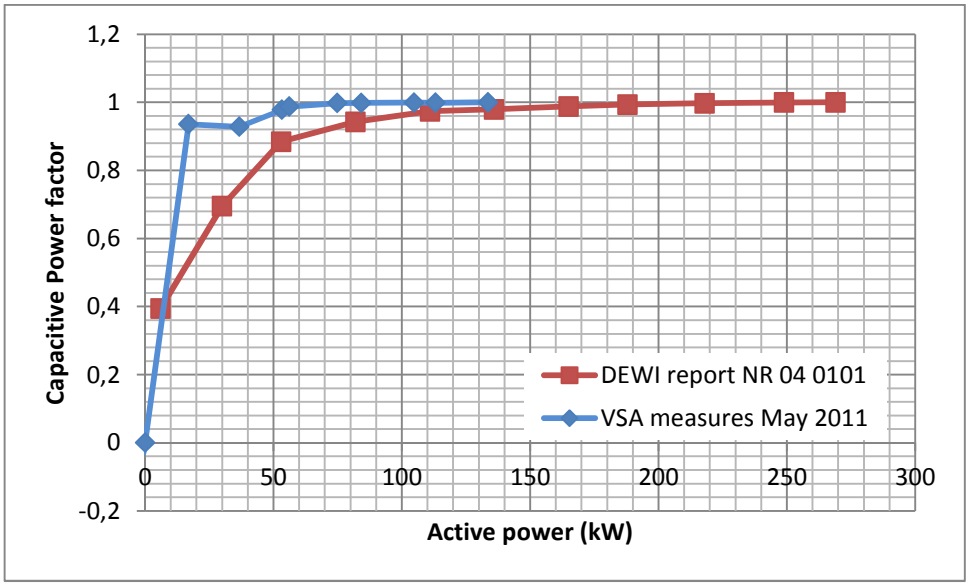


Figure 3 - Measured Power Factor versus active power – DEWI 2004 [S1]

8.2 Extreme power values

Extreme power values are given as per IEC 61400 requirements versus the hold time.

	Averaging time (sec)	Active power (kW)	Ratio to nominal power	Reactive power (kVAR inductive)
Maximum measured power $P_{0.2}$	0.2	421	1.53	86
Maximum measured power P_{60}	60.0	279	1.01	4
Maximum measured power P_{600}	600.0	273	0.99	1

Table 2 - Extreme power figures – DEWI 2004 [S1]

8.3 Fault current contribution

Fault current contribution	
Peak asymmetrical short circuit current at 10ms (i_p) for a 3φ short circuit fault at generator terminal	6,9 kA
RMS value of the initial symmetrical short circuit current ($I_{k''}$) for a 3φ short circuit fault at generator terminal	3,76kA
RMS value of the symmetrical short circuit current at 100ms ($Ik_{(100)}$) for a 3φ short circuit fault at generator terminal	0,78kA

Table 3 – Fault current contribution figures

Note : cable and transformer impedances have to be taken into account for calculation at delivery point

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8.4 Harmonics

IEC 61400-21 standard does not require measurement or assessment of short-duration harmonics caused by wind turbine start-up or other switching operations.

The GEV MP only generates harmonics with its soft starter during the few seconds (maximum of 2 seconds) necessary to synchronize the generator speed to the grid frequency. That duration is too short to have an impact on the grid or on the consumers as per IEC standard statement.

8.5 Flicker

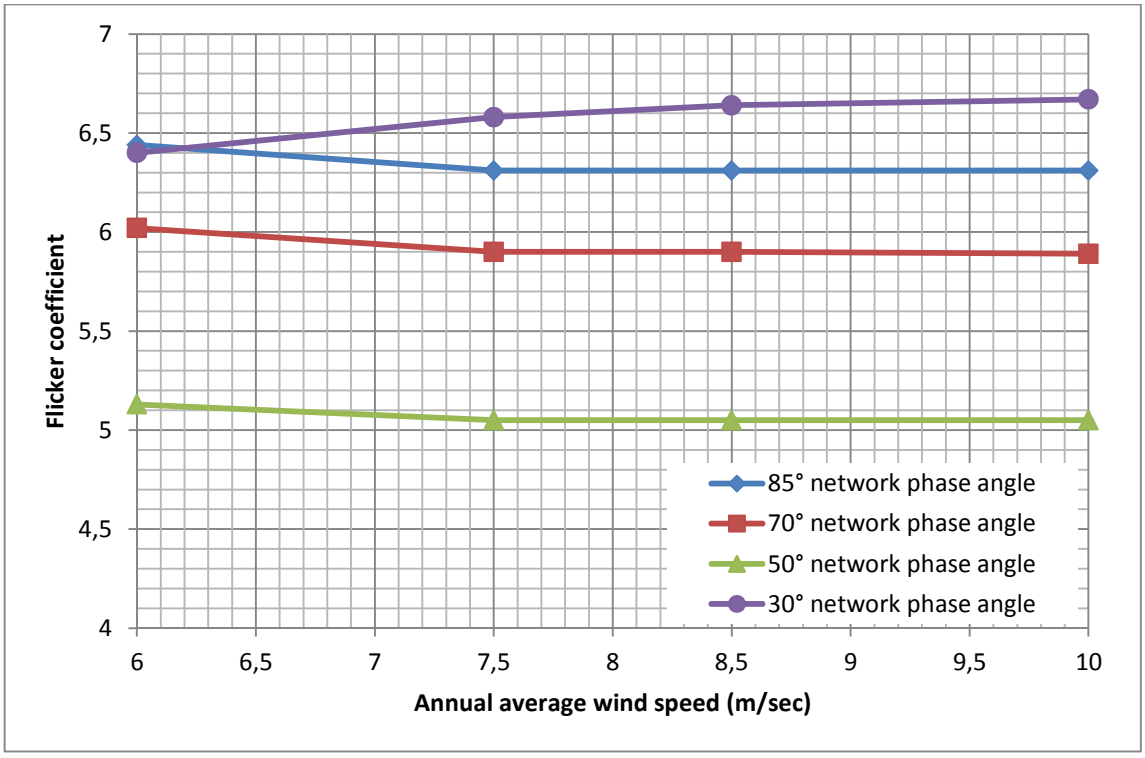


Figure 4 - Flicker coefficients versus annual wind speed - DEWI 2004 [S1]

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9 TRANSIENT MODES AT RATED WIND SPEED

9.1 Maximum number of switching operations

	Time frame (min)	Switching operation at rated wind speed	Operation from small to large generator
Maximum switching operations within a 10 minutes time period, N_{10}	10	1	1
Maximum switching operations within a 2 hours time period, N_{120}	120	4	4

Table 4 – Maximum number of switching operations

9.2 Behaviour during startup at rated wind speed

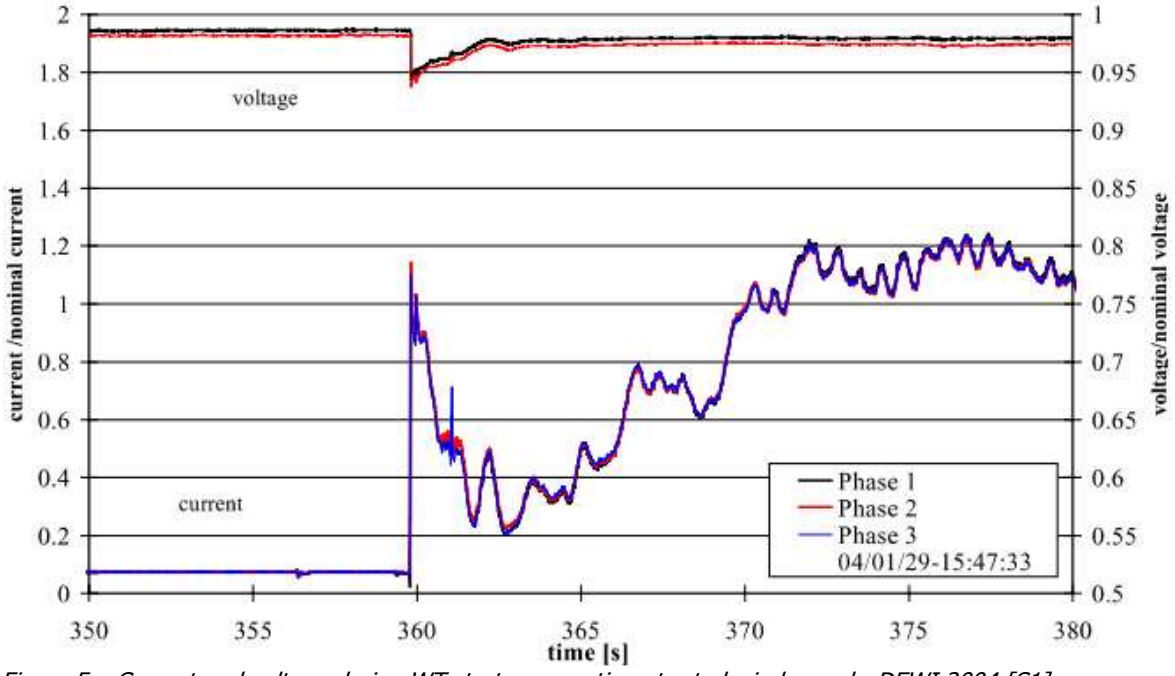


Figure 5 – Current and voltage during WT startup operation at rated wind speed - DEWI 2004 [S1]

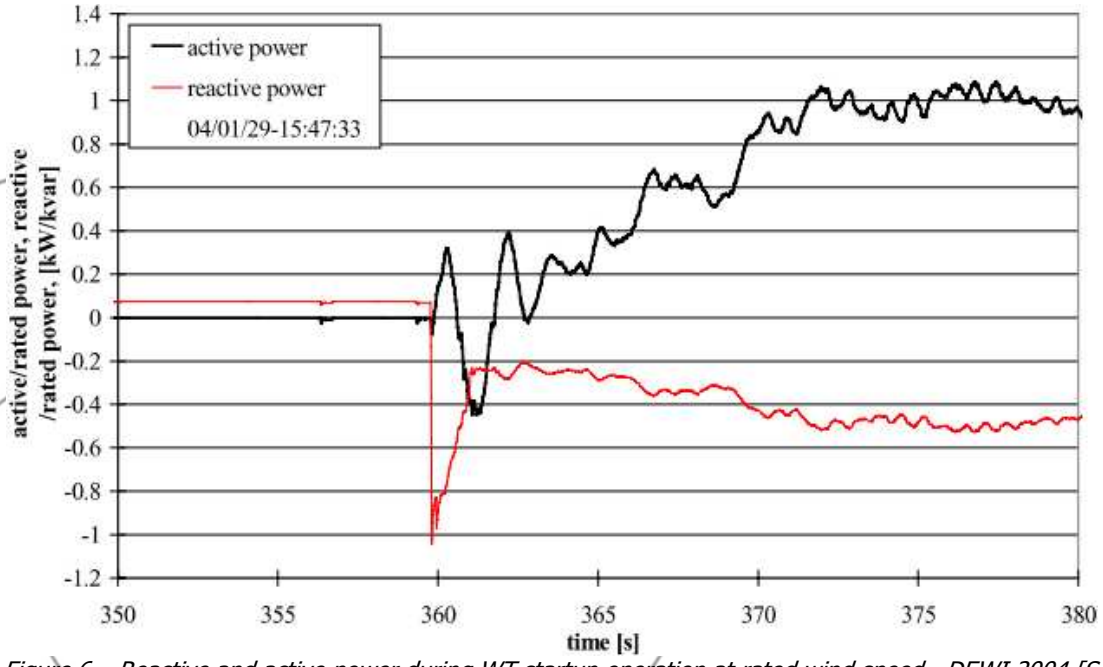


Figure 6 – Reactive and active power during WT startup operation at rated wind speed - DEWI 2004 [S1]

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9.3 Load shedding at rated wind speed

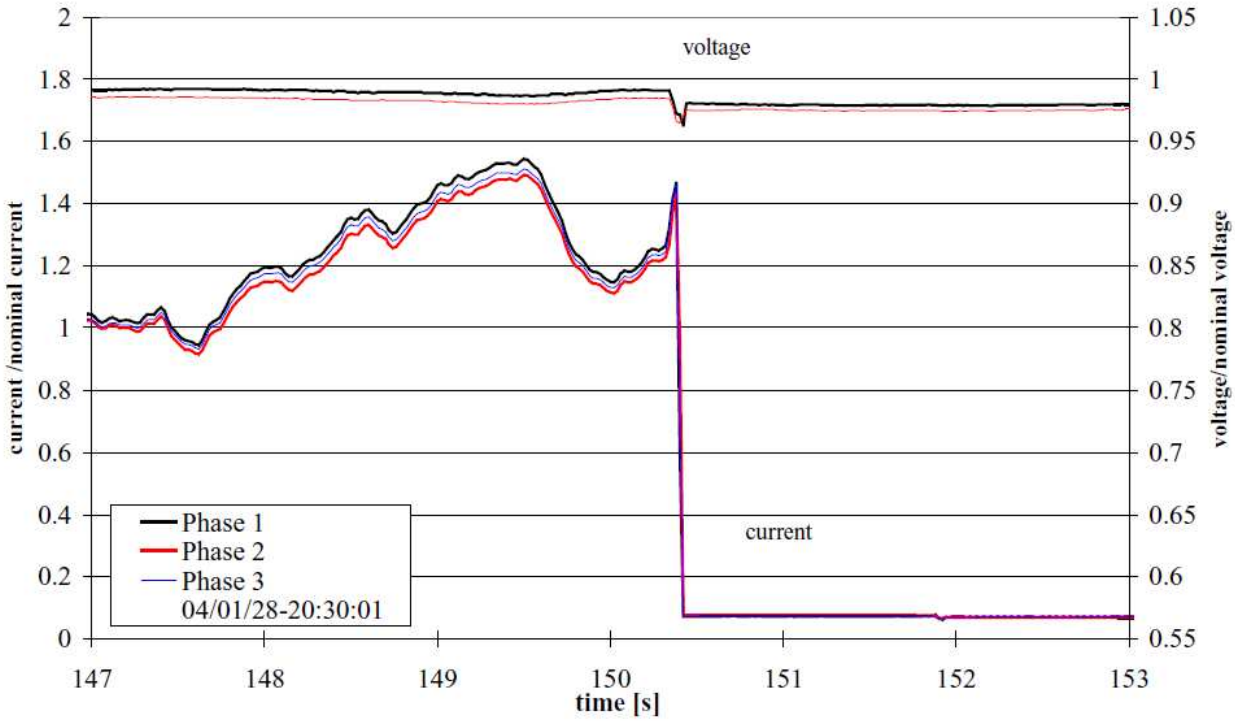


Figure 7 – Current and voltage during load shedding at rated wind speed - DEWI 2004 [S1]

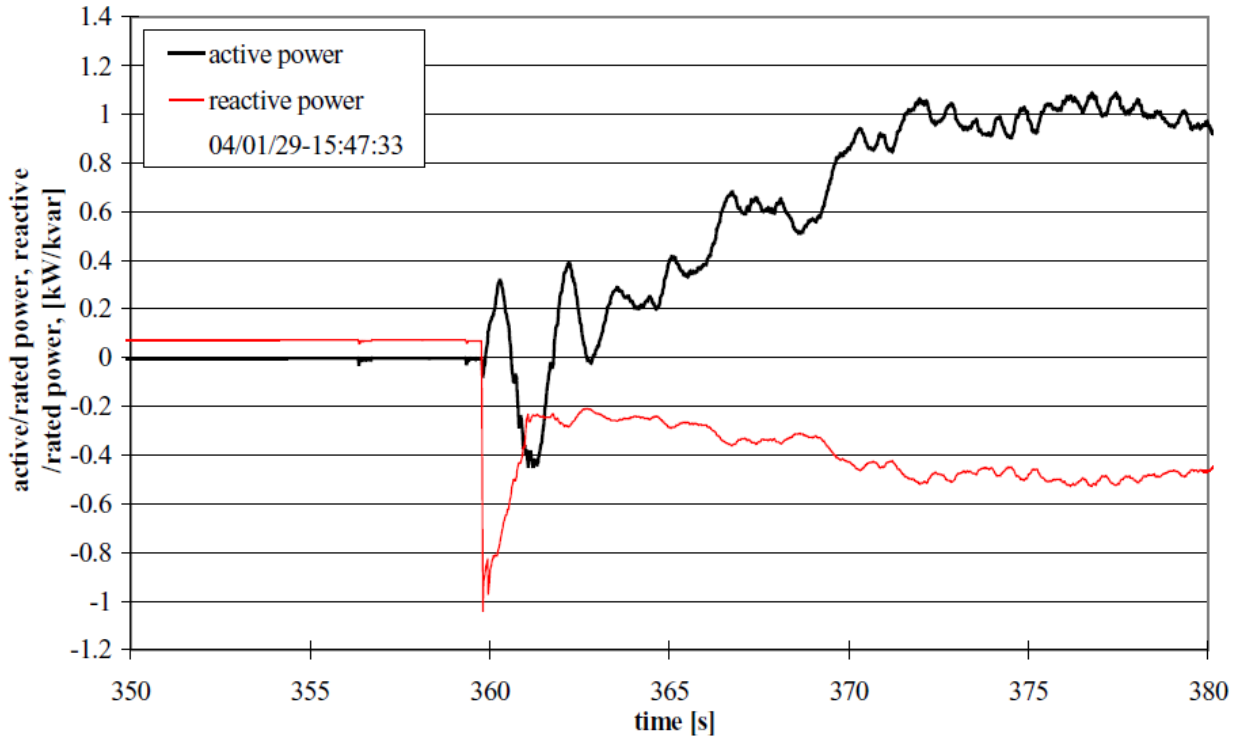


Figure 8 – Reactive and active power during load shedding at rated wind speed - DEWI 2004 [S1]

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10 TRANSIENT MODES AT CUT-IN WIND SPEED

10.1 Maximum number of switching operations

	Time frame (min)	Number of switching operation
Maximum measured power $P_{0.2}$	10	2
Maximum measured power P_{60}	120	10

Table 5 – Maximum number of switching

10.2 Low speed generator behavior during startup at cut-in wind speed

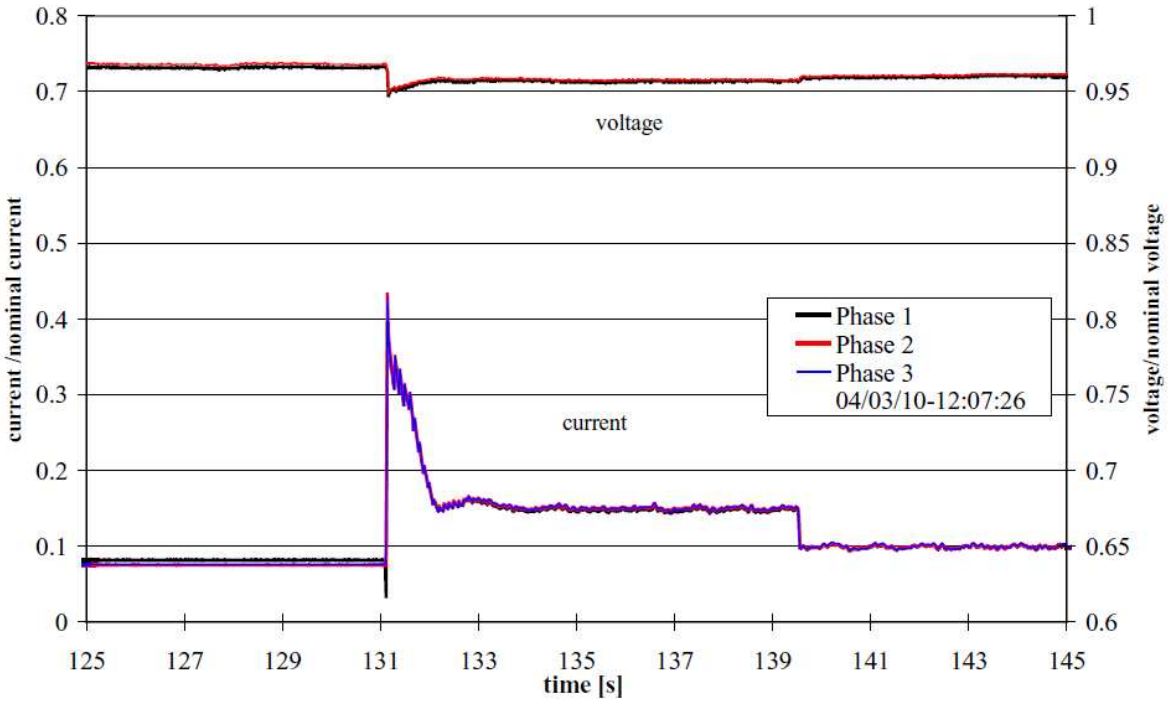


Figure 9 – Current and voltage during low speed generator startup at cut-in wind speed - DEWI 2004 [S1]

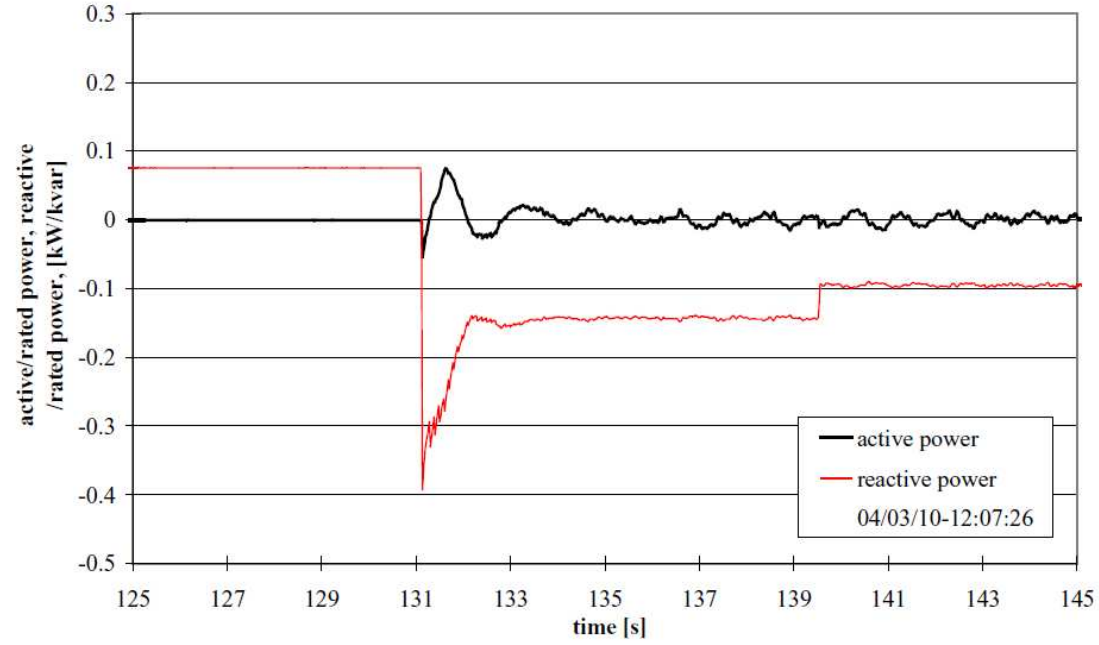


Figure 10 – Reactive and active powers during low speed generator startup at cut-in wind speed - DEWI 2004 [S1]

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11 SWITCHING OPERATIONS BETWEEN HIGH/LOW SPEED GENERATORS

11.1 Maximum number of switching operations

	Time frame (min)	Switching operation from low to high speed
Maximum switching operations within a 10 minutes time period, N_{10}	10	1
Maximum switching operations within a 2 hours time period, N_{120}	120	4

Table 6 – Maximum number of switching operations

11.2 Behavior during low to high speed generator changeover

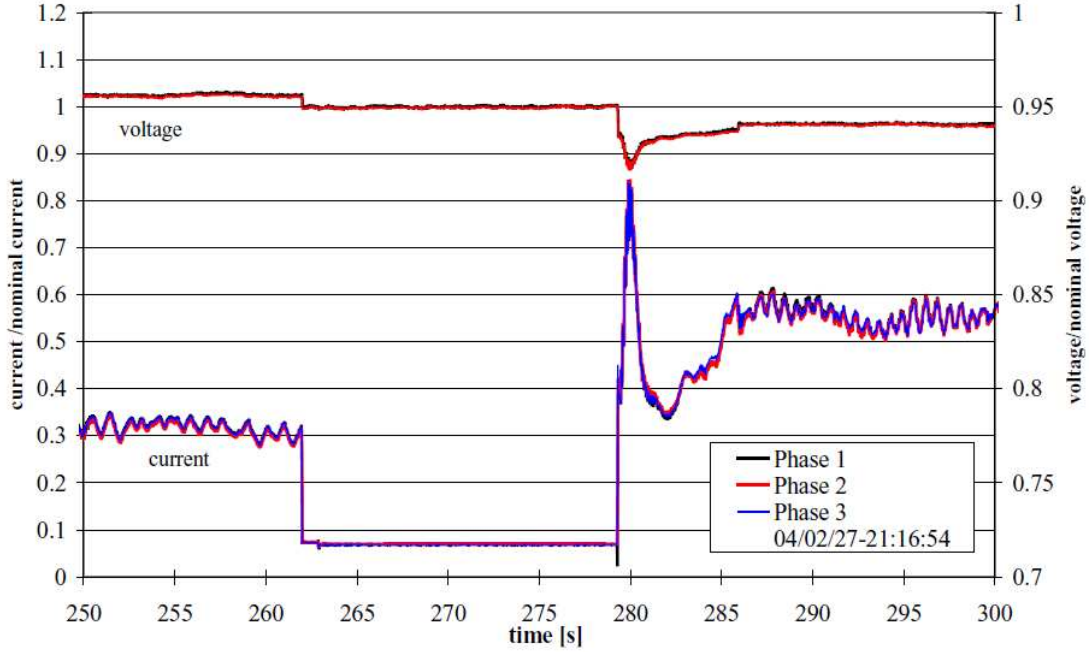


Figure 11 – Current and voltage during low to high speed generator changeover - DEWI 2004 [S1]

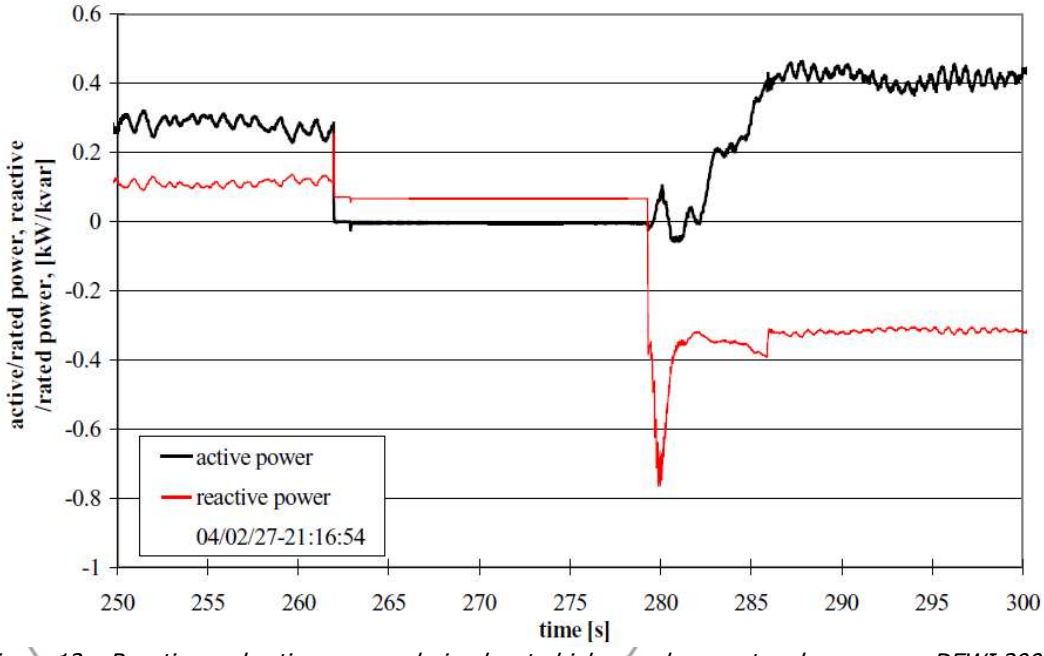


Figure 12 – Reactive and active powers during low to high speed generator changeover - DEWI 2004 [S1]

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11.3 Behavior during high to low speed generator changeover

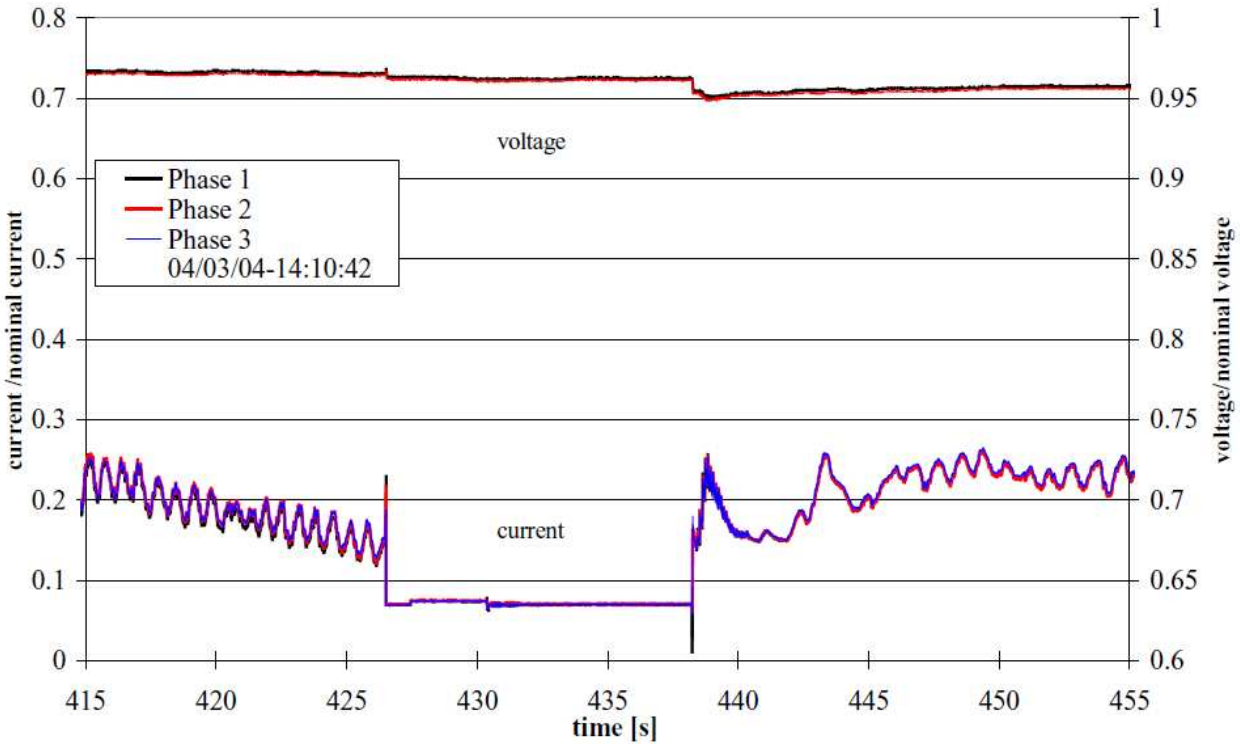


Figure 13 – Current and voltage during high to low speed generator changeover - DEWI 2004 [S1]

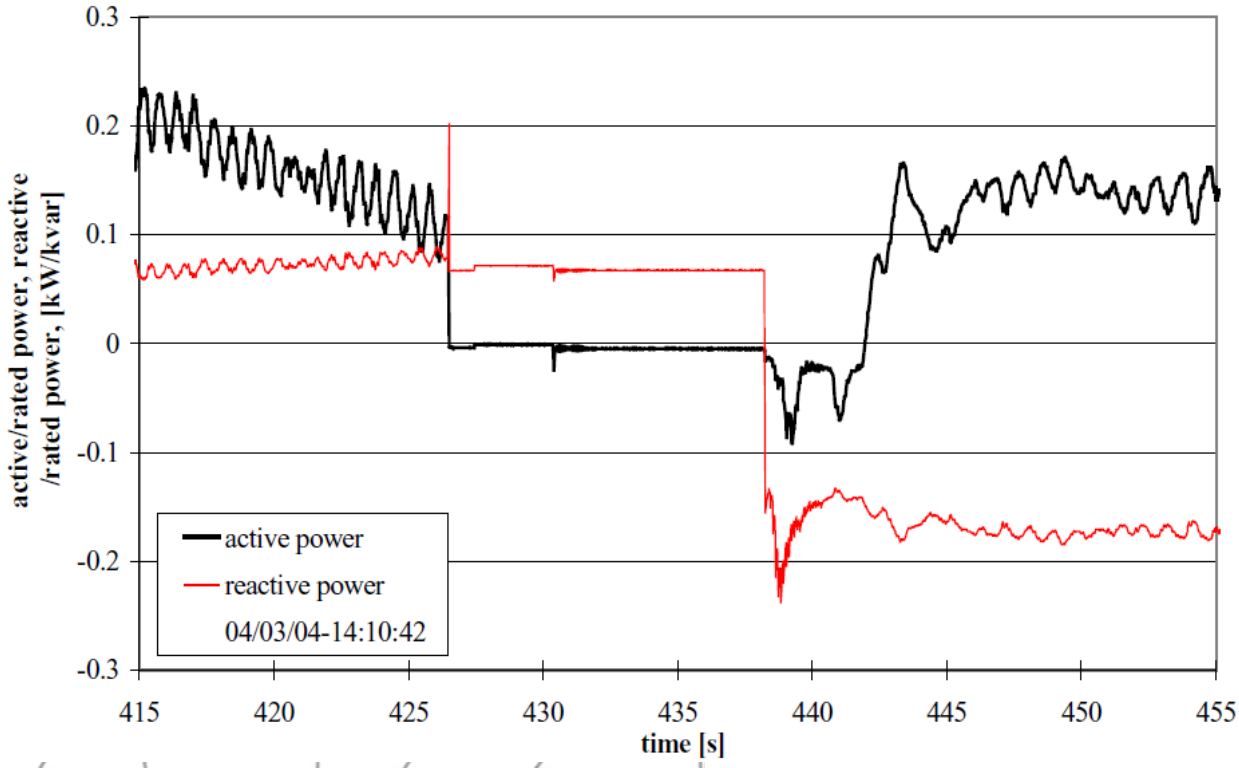


Figure 14 – Reactive and active powers during high to low speed generator changeover - DEWI 2004 [S1]

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12 FLICKER DURING SWITCHING OPERATIONS

12.1 Voltage change factor

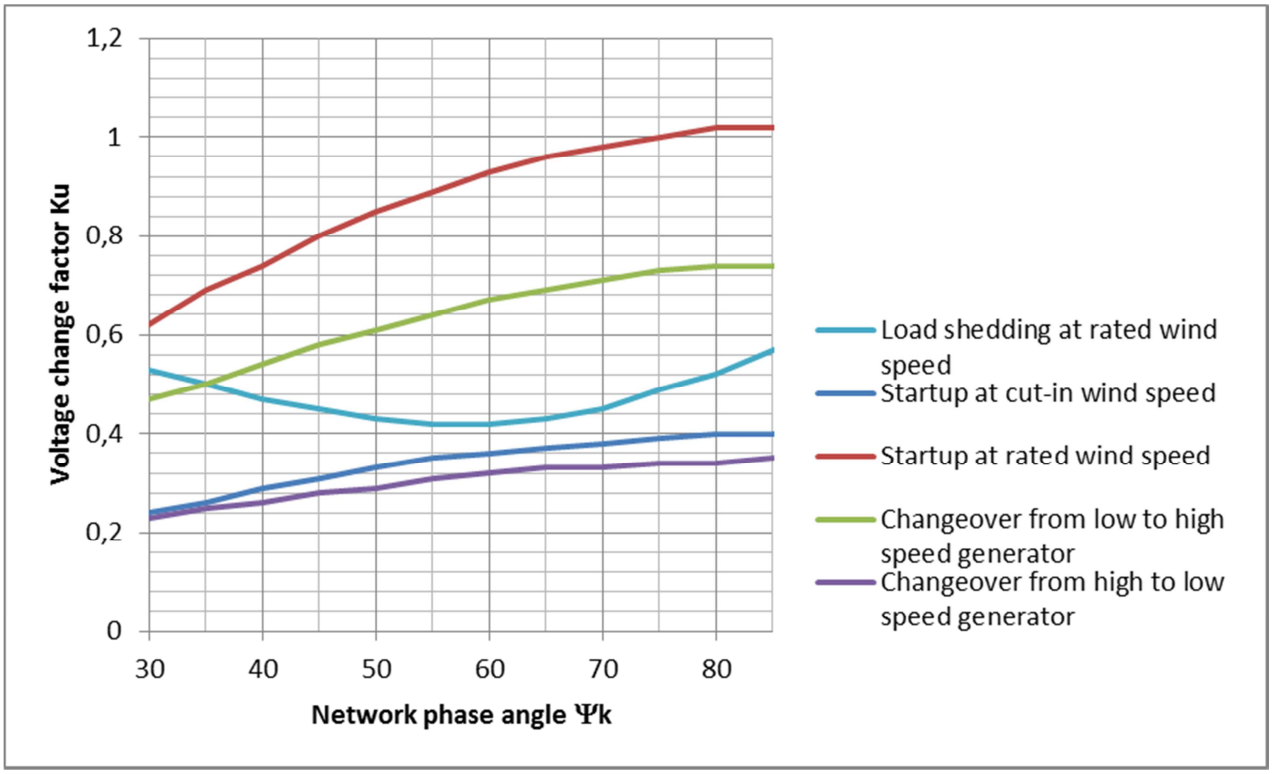


Figure 15 – Voltage change factor during switching operations - DEWI 2004 [S1]

12.2 Frequency change factor

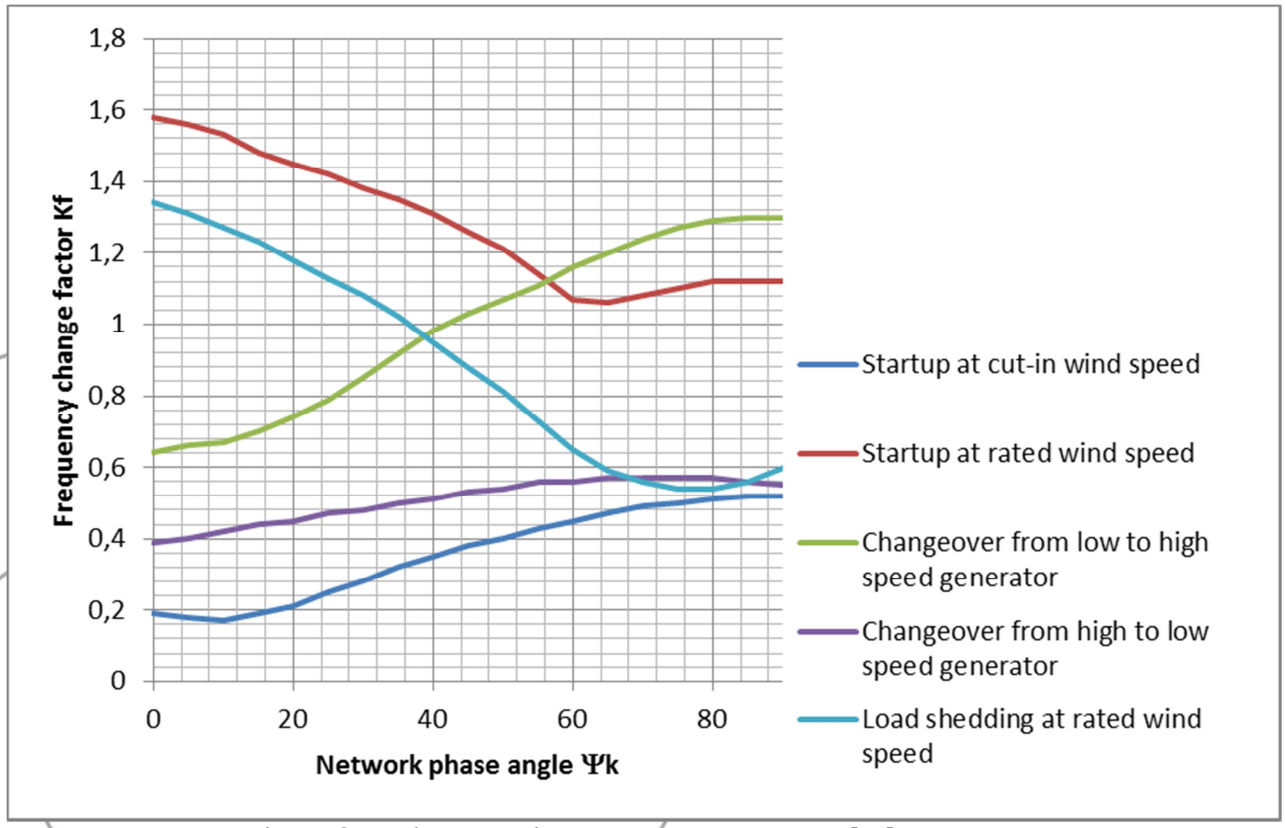


Figure 16 – Frequency change factor during switching operations - DEWI 2004 [S1]

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13 GRID CODE COMPLIANCES

Notwithstanding all data published in the previous chapters, the actual compliance with specific grid code/Utilities requirements cannot be definitely determined. Indeed, compliance with grid codes is required to be achieved at the Point of Common Coupling (PCC), and there, network model data and power station model data need to be computed to determine the overall systemic electrical behavior.

Often, Grid codes/Utilities will require the installation of Grid protection hardware, such as protection relays and disconnect switches.

Therefore, VSA emphasizes the necessity of performing an electrical interconnection study in order to assess the real expectable network stability, especially on weak and/or island grids.

At last, based upon VERGNET's installation reference list, it can be stated that projects using the GEV MP 275kW can achieve compliance with most grid codes, amongst which:

- France for overseas islands
- France for mainland
- Japan
- Taïwan
- Australia
- Chile
- United Kingdom
- Lithuania
- USA
- Cuba
- …

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