Operational Experiences

Integration of Medium to High Penetration Wind without Energy Storage

- **AVEC Operational Experiences**
- AVEC's experiences with integration of Medium to High Penetration Wind without Energy Storage
- AVEC has four villages with significant wind installations:
- Wales two AOC turbines, secondary loads and storage (2001)
- Selawik with four AOC turbines, secondary load and no storage (2003)
- Toksook Bay with three Northwind 100s, secondary load and no storage (2005)
- Kasigluk with three Northwind 100s, secondary load and no storage (2006)
- Except for Wales, AVEC has acted as the systems integrator in each case. These three sites already had recently installed advanced switchgear for dispatching the diesels so this software was expanded by AVEC to include wind and secondary load control as well.

- The responsibilities of the dispatch software are:
- Switch engines as load changes or units enter or leave active service, in order to maximize fuel efficiency with minimal interrupts of service.
- Minimize outage durations by automatically starting generators and closing service to sections of the village one at a time.
- Allow wind turbines to run when wind permits, unless the diesel drops below minimum allowable loading.
- If so, then increase the command setpoint to the secondary load controller
- If the SLC is not able to absorb the excess generation, then one or more wind turvbines may be curtailed.
- A calculation of required spinning reservice is done , and this requirement may increase the size of the engine running during wind geneation.

Next Chart

- The Yellow represents the diesel capacity, You can see that at several times is has reacted to differenet engine changes.

- The Green line indicated the load from the vlllage, we keep the generation higher than the need.
-
- The line is the actual power supplied from the diesel generate. Wind output allows this line to be lower that the village load sometimes.

KOHLER Power Systems

Monitor | Request Capacity | Feeder | 24 Hour Demand | Alarm | History | Time/Date

Not in Auto | Alarm

07:01:04

kW

1600
1400
1200
1000
800
600
400
200
0

Date 04/03 04/03 04/03 04/03 04/03 04/03 04/03 04/03 04/03 04/04 04/04 04/04 04/04

Time 07:45 09:45 11:45 13:45 15:45 17:45 19:45 21:45 23:45 01:45 03:45 05:45 07:45

Start Date

04/03/2007

Start Time

07:45:11

Max kW Demand every 5 Min
10 Days of History

Trend Duration
(Hours from Start)

24

Cursor Value

199 MaxKw

500 On Line Gen

360 Village Load

Last 5 Min Max

312 MaxKw

500 On Line Gen

406 Village Load

User

6 Min

04/04/2007 07:45:35

Integration Concerns

- Frequency Stability (electronically injected diesel engines are very fast to respond)
- Voltage Stability (A good three phase RMS sensing digital voltage regulators with good tuning helps)
- Engine Dispatch (Software that AVEC, as the responsible operating authority, has full control over.)
- Preventing of reverse power (Use of the secondary load first, then turn off one or more turbines if that does not work.)
- Managing excess energy (Use of the secondary load first, then turn off one or more turbines if that does not work.
- Ability to allocate responsibility when issues arise (Good metering on the wind turbines, the secondary load, and the diesels helps. This metering should include high speed logging with timestamping. The devices should be networked for remote access and downloads.
- Remote Monitoring This information should be accessible enough, and should be distributed widely to the right people

ENERGY SYSTEMS

Gateway

Login time: 4/25/2008

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System Overview | WTG 1 | WTG 2 | WTG 3 | DEG 1 | DEG 2 | DEG 3 | Heat Recovery | Control Module | Metering | Alarms | Events | Trends

Toksook Bay System Overview

WTG 1 - NW100

WTG State	Online	
Engy Produced	429,318	kWh
Time Online	15,403	hrs
Yaw Azim	316	deg
Power	39	kW

WTG 2 - NW100

WTG State	Online	
Engy Produced	390,090	kWh
Time Online	13,771	hrs
Yaw Azim	305	deg
Power	46	kW

WTG 3 - NW100

WTG State	Online	
Engy Produced	441,321	kWh
Time Online	15,383	hrs
Yaw Azim	307	deg
Power	44	kW

W/D SCADA

Pk Wnd Pwr Allowed	399	kW

WTG Bus

Exp MWh	1,261	A - G Volts	283.8	A Amps	157.5
kW	129.7	B - G Volts	284.5	B Amps	160.7
Hz	59.89	C - G Volts	284.8	C Amps	164.7

DEG 1 - Kohler Series 60

Status	Auto Ready	
Engy Produced	1,275	MWh
Number of Starts	1,577	
Run Hrs	7,538	
Power	0	kW

DEG 2 - Caterpillar 3456

Status	Manual Online	
Engy Produced	2,896	MWh
Number of Starts	1,739	
Run Hrs	13,181	
Power	172	kW

DEG 3 - Kohler 12V2000

Status	Auto Ready	
Engy Produced	958	MWh
Number of Starts	727	
Run Hrs	3,747	
Power	0	kW

Nightmute

Real Pwr	70	kW
Reac Pwr	-0	kVAR

Phs Cur A, B, C (Amps): 91 | 96 | 62

Tok Bay West Side

Real Pwr	64	kW
Reac Pwr	19	kVAR

Phs Cur A, B, C (Amps): 71 | 100 | 66

Tok Bay East Side

Real Pwr	-62	kW
Reac Pwr	16	kVAR

Phs Cur A, B, C (Amps): 86 | 63 | 83

Tununak

Real Pwr	95	kW
Reac Pwr	26	kVAR

Phs Cur A, B, C (Amps): 90 | 133 | 134

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HMI for Toksook Bay, Alaska

Distributed ENERGY SYSTEMS

SmartView Gateway

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k to menu

ystem Overview | WTG 1 | WTG 2 | WTG 3 | DEG 1 | DEG 2 | DEG 3 | Heat Recovery | Control Module | Metering | Alarms | Events | Trends

Time Online	15,403	hrs	
Yaw Azim	316	deg	
Power	60	kW	

Time Online	13,772	hrs	
Yaw Azim	305	deg	
Power	51	kW	

Time Online	15,383	hrs	
Yaw Azim	307	deg	
Power	53	kW	

Phs Cur A, B, C (Amps)

90	77	53

/D SCADA

Pk Wnd Pwr Allowed	399	kW

WTG Bus

Exp MWh	1,261	A - G Volts	285.0	A Amps	201.7
kW	163.7	B - G Volts	285.7	B Amps	203.7
Hz	59.79	C - G Volts	286.1	C Amps	207.3

Tok Bay West Side

Real Pwr	66	kW
Reac Pwr	16	kVAR

Phs Cur A, B, C (Amps)

65	107	70

Tok Bay East Side

Real Pwr	-93	kW
Reac Pwr	16	kVAR

Phs Cur A, B, C (Amps)

124	104	112

EG 1 - Kohler Series 60

Status	Auto Ready	
Engy Produced	1,275	MWh
Number of Starts	1,577	
Run Hrs	7,538	
Power	0	kW

DEG 2 - Caterpillar 3456

Status	Manual Online	
Engy Produced	2,896	MWh
Number of Starts	1,739	
Run Hrs	13,181	
Power	135	kW

DEG 3 - Kohler 12V2000

Status	Auto Ready	
Engy Produced	958	MWh
Number of Starts	727	
Run Hrs	3,747	
Power	0	kW

Tununak

Real Pwr	94	kW
Reac Pwr	25	kVAR

Phs Cur A, B, C (Amps)

87	124	138

Amb Temp	23	°F
Wind Speed	25	mph
Tot Gen Pwr	276	kW

DEG Bus

kW	112.0	Imp kWh	0	A - B Volts	494	A Amps	138
kVAR	41.9	Exp MWh	3,407	B - C Volts	493	B Amps	228
Hz	60.03	Pwr Fact	0.94	C - A Volts	495	C Amps	172

Boiler

Real Pwr	7	kW
Reac Pwr	-0	kVAR

Phs Cur A, B, C (Amps)

8	8	8

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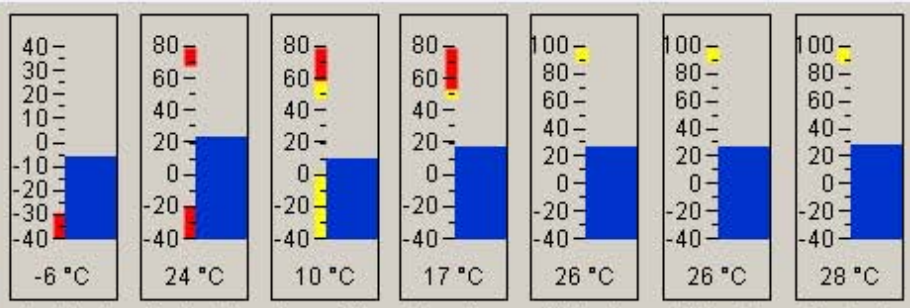
Toksook Bay Wind Turbine Generator 1

Turbine State	Online		Alarms	No Alarms	Reset Faults
Time Online	15,403	hrs	HMI	WTG Enabled	Enable WTG
Engy Produced	429,331	kWh	SCADA	WTG Enabled	Disable WTG

1-min Wnd Spd	11.3	m/s	
10-min Wnd Spd	11.0	m/s	
Time Available	1,924	hrs	
Reac Pwr SP	0.0		
Reac Pwr New SP			Set
Pwr Fact SP	1.00		
Pwr Fact New SP			Set
PF Lead/Lag	Lead		

Lead | Lag

Write Set Points



Yaw Turns	-1.1	Gen Fans	On	Nac Service Sw	Ready
Yaw Azim	315.6 deg	Wall Fans	Off	Base Service Sw	Ready

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ystem Overview | WTG 1 | WTG 2 | WTG 3 | DEG 1 | DEG 2 | DEG 3 | Heat Recovery | Control Module | Metering | Alarms | Events | Trends

tside Ambient Air Temp	23.6	°F
nside Ambient Air Temp	77.6	°F
Exhaust Temp R	157	°F
Exhaust Temp L	96	°F
Hydron Inlet	174.3	°F
Hydron Outlet	185.0	°F
Real Power	139.0	kW
eactive Power	78.0	KVAR
Total Energy	2,895,782	kWh
Engine Status	Manual Online	
Number of Starts	1,739	
Run Time	13,181	hours
Hrs to Oil Change	-1,137	
Engine Speed	1,804.0	RPM
Engine Temp	196.0	°F
Jacket Temp	196	°F
Oil Temp	230	°F
Oil Pressure	35	PSI
Aftercooler Return Temp		°F
Vibration, Back X	0	g
Vibration, Back Y	0	g
Vibration, Front X	0	g
Vibration, Front Y	0	g
Unallocated Temp	100	°F

Lube Level Low
Lube Level High
Coolant Level Low
Coolant Level SD

Aftercooler

VFD Status	VFD Mode	
Standby	Auto	
Temp Set Pt	195.0	°F
New Set Pt		Set
Outlet Temp	195.6	°F
Inlet Temp		°F
Cntlr Output	29.6	%
Valve Status	No Comms	
Fan Speed	0.0	%
Fan Power	0.00	kW

VFD Status	VFD Mode	
Running	Auto	
Temp Set Pt	100.0	°F
New Set Pt		Set
Outlet Temp	100.6	°F
Inlet Temp		°F
Cntlr Output	39.80	%
Fan Speed	7.0	%
Fan Power	0.15	kW

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ystem Overview | WTG 1 | WTG 2 | WTG 3 | DEG 1 | DEG 2 | DEG 3 | Heat Recovery | Control Module | Metering | Alarms | Events | Trends

Plant Feeder (Boiler)

Real Power	4.9	kW	L1 Current	6.0	Amps
Peak Power		kW	L2 Current	6.0	Amps
Reac Power	-0.1	kVAR	L3 Current	6.0	Amps
Exp. Energy	0.0	kWh			
ower Factor	1.0				

Inside Ambient Air Temp 93.7 °F

Community Building

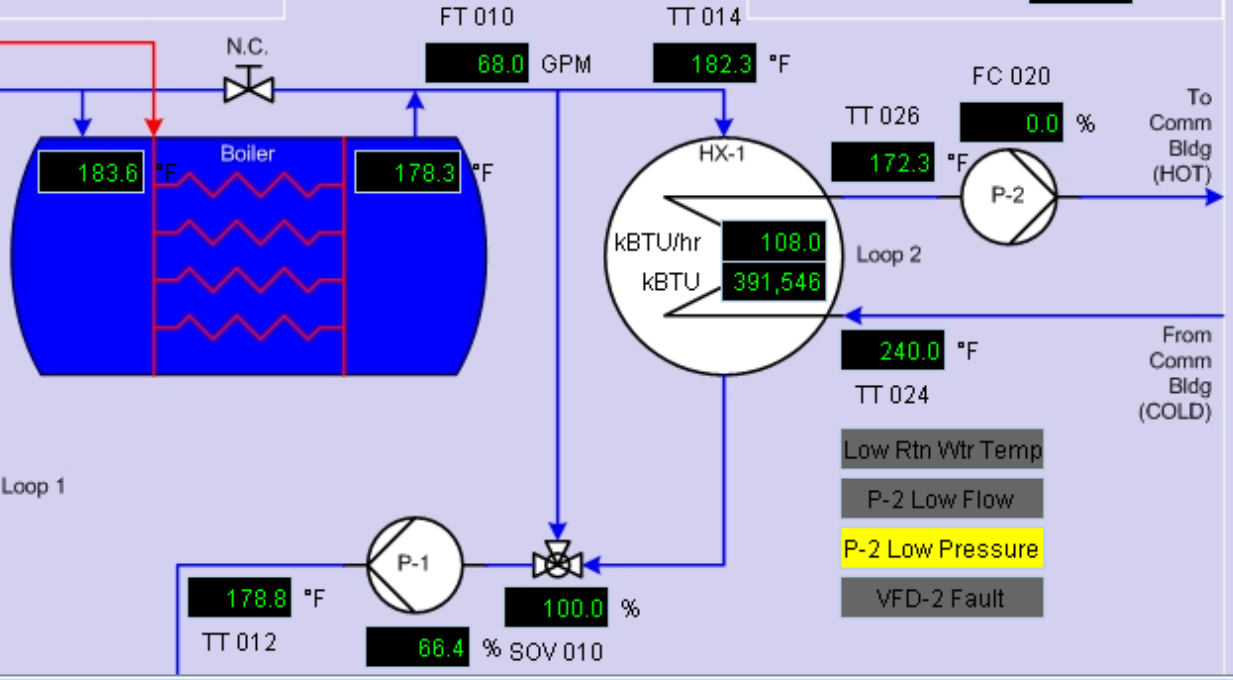
HX-2 Total Therm Engy	391,546	kBTU
HX-2 Heat Rate	108.0	kBTU/h
HX-3 Total Therm Engy	212,264	kBTU
HX-3 Heat Rate	42.0	kBTU/h

Secondary Load Controller

Mode	Power Control	
Bus Frequency	59.98	Hz
Cabinet Temp	93.7	°F
Actual Capacity	217.4	kW
Effect Capacity	217.4	kW

Alarm Off	Available
Warning Off	Offline
Operating	Enabled

Hydr Flow Alm P-1
P-1 Low Flow
P-1 Low Pressure



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ystem Overview | WTG 1 | WTG 2 | WTG 3 | DEG 1 | DEG 2 | DEG 3 | Heat Recovery | Control Module | Metering | Alarms | Events | Trends

Plant Batteries and Charging System

Charger Status	n/a
DC Voltage	
Charging Amps	
Local Batt Voltage Unit #1	
Local Batt Voltage Unit #2	
Local Batt Voltage Unit #3	
Power Supply Status #1	
Power Supply Status #2	
Power Supply Status #3	

Hydronic System

Pump #1 Status	n/a	
Pump #2 Status	n/a	
System Temp		°F
Flow Rate		GPM
Pressure		PSI

Fire Suppression System

Panel Status	n/a
Future Use	
Future Use	
Future Use	

Plant Fuel System

Panel Status	n/a	
Day Tank P1 Status	Off	
Day Tank P2 Status	Off	
Motor Operated Valve	Closed	
Fuel Meter Reg Total	145,355	gals
Last Fuel Pumped	81.1	gals
Energy at Last Fill	1,099	kWh
Efficiency at Last Fill	13.5	kWh/gal
Fuel Supply Temp	102.0	°F
Fuel Return Temp	152.4	°F

Day Tank Full
Day Tank Low
Day Tank Overfill
Day Tank Crit Low

Weather Station

Wind Speed	
Outside Temp	
Wind Direction	
Barometric Pressure	

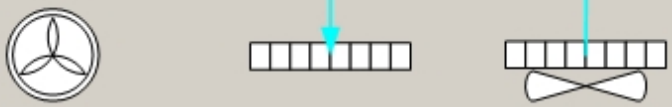
Waste Oil Blender

Oil Level	0	in
Blend Ratio	0.6	%
Lube Oil Blended	0	gals

OK

Heating and Ventilation System

Ambient Temp		°F
Control Module Temp	98.8	°F
Living Quarters Temp		°F



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ystem Overview | WTG 1 | WTG 2 | WTG 3 | DEG 1 | DEG 2 | DEG 3 | Heat Recovery | Control Module | Metering | Alarms | Events | Trends

Toksook Bay Metering

Generation

Diesel Generation		Wind Generation
3,407	Exp Engy (MWh)	1,261
104	Real Power (kW)	149
48	Reac Pwr (kVAR)	
60.03	Bus Freq (Hz)	60.07
0.91	Pwr Fact	
143.6	L1 Amps	64.8
228.8	L2 Amps	65.3
162.8	L3 Amps	65.9
	L1-N Volts	286.7
	L2-N Volts	286.7
	L3-N Volts	287.3
494.0	L1 - L2 Volts	496.9
494.0	L2 - L3 Volts	494.3
495.0	L3 - L1 Volts	496.9
114.0	Peak Pwr (kW)	165.0
298	L1 Max Amps	
432	L2 Max Amps	
344	L3 Max Amps	

Generation Totals

Total Real Pwr	252	kW
Total Reac Pwr		kVAR
Total Exp Engy	4,668	MWh
Outage Count	1,500	

East Side Feeder - No WTG

Real Power	59	kW
Total Exp Engy	1,261	kWh

Distribution Feeder Metering

	Nightmute	West Side	East Side	Tununak	Boiler
Exp Engy (MWh)	30	2,189	1,262	1,853	89
Imp Engy (MWh)	0	0	439	0	0
Real Pwr (kW)	67	61	-90	93	1
Reac Pwr (kVAR)	-3	18	21	25	-0
Frequency (Hz)	60.03	60.04	59.99	60.03	60.04
Power Factor	-1.00	0.96	-0.97	0.97	1.00
L1 Amps	77	71	116	91	2
L2 Amps	109	93	105	118	1
L3 Amps	55	64	111	139	0
Max Real Pwr (kW)	71	66	-0	109	4
Max App Pwr (kVA)	71	70	75	113	4
Closure Count	22	16	13	50	0
L1 Max Amps	121	124	186	134	78
L2 Max Amps	130	132	165	182	77
L3 Max Amps	76	101	179	175	77

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Acknowledge | All

Time Active	Name	Message	Time Clear	Time Acked	Category
8-04-22 10:19:47	WTG3_F_A41SN_S4Timeout	State 4 timeout	2008-04-22 10:20:27		1
8-04-22 10:18:48	WTG3_F_A23SL_BrkRelFB	Mechanical brake did not r...	2008-04-22 11:53:22		1
8-04-17 02:11:43	HRC_W_P2LoopPrsLo	P-2 Low Pressure (N.O.) (L...		2008-04-22 03:54:09	2

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HMI for Toksook Bay, Alaska

Distributed ENERGY SYSTEMS

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ystem Overview | WTG 1 | WTG 2 | WTG 3 | DEG 1 | DEG 2 | DEG 3 | Heat Recovery | Control Module | Metering | Alarms | Events | Trends

ents from: One Day or from: 2008-04-24 00:48:16 to: 2008-04-25 00:48:16 Show: All Export

ent Name: or or Viewing results 1 to 500 < 500 > Refresh

Timestamp	Event Type	Name	Value
8-04-24 18:37:23	EVT	WTG2_D_YawState	3
8-04-24 18:37:06	EVT	WTG3_D_YawState	1
8-04-24 18:36:53	EVT	WTG3_D_YawState	3
8-04-24 18:36:53	EVT	WTG3_D_YawREvtCntr	17508
8-04-24 18:21:59	EVT	WTG2_D_DSPWarning2	0
8-04-24 18:21:54	EVT	WTG2_D_DSPWarning2	4
8-04-24 18:18:54	EVT	WTG2_D_DSPWarning2	0
8-04-24 18:18:52	EVT	WTG2_D_DSPWarning2	4
8-04-24 18:16:13	EVT	WTG2_D_YawState	1
8-04-24 18:16:07	EVT	WTG2_D_YawREvtCntr	11948
8-04-24 18:16:07	EVT	WTG2_D_YawState	3
8-04-24 18:03:17	EVT	WTG2_D_DSPWarning2	0
8-04-24 18:03:15	EVT	WTG2_D_DSPWarning2	4
8-04-24 17:58:23	EVT	WTG2_D_DSPWarning2	0
8-04-24 17:58:21	EVT	WTG2_D_DSPWarning2	4
8-04-24 17:37:17	EVT	KOH_D_Gen3Status	0
8-04-24 17:34:18	EVT	DEG3_D_JacketVFDStatus	1
8-04-24 17:33:19	EVT	DEG2_D_JacketVFDStatus	2
8-04-24 17:33:04	EVT	WTG3_D_YawState	1
8-04-24 17:33:00	EVT	WTG3_D_YawREvtCntr	17507
8-04-24 17:33:00	EVT	WTG3_D_YawState	3
8-04-24 17:32:01	EVT	DEG3_D_AftClrVFDStatus	1
8-04-24 17:28:05	EVT	DAY_D_MtrOperVlv	0
8-04-24 17:28:03	EVT	DAY_D_DayTnkFull	0

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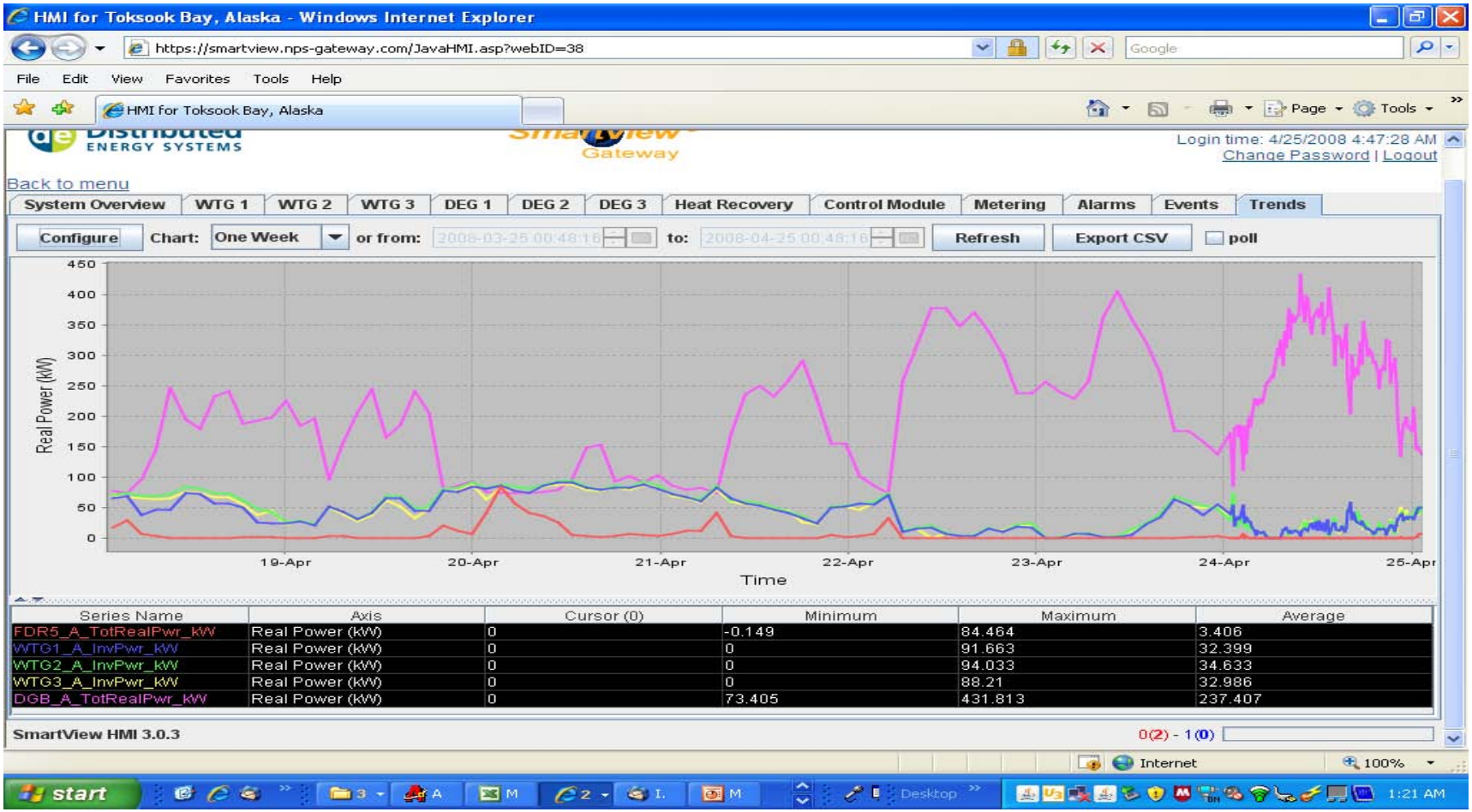
One week of diesel, wind and Secondary Load Control



Series Name	Axis	Cursor (0)	Minimum	Maximum	Average
FDR5_A_TotRealPwr_kW	Real Power (kW)	0	-0.149	84.464	3.406
WTG1_A_InvPwr_kW	Real Power (kW)	0	0	91.663	32.399
WTG2_A_InvPwr_kW	Real Power (kW)	0	0	94.033	34.633
WTG3_A_InvPwr_kW	Real Power (kW)	0	0	88.21	32.986
DGB_A_TotRealPwr_kW	Real Power (kW)	0	73.405	431.813	237.407

When first Toksook Bay was started, it was un stable

- Fortunately we had installed on meterint cable of logging and timestamping oyer our network. The next pictures shows some SATEC meters.

106
.7
.5
POWER FACTOR
FEEDER BREAKER NO. 1
OPEN
TRIPPED
CLOSED
BREAKER CONTROL
OPEN
CLOSE
MANUAL
AUTO
FEEDER BREAKER NO. 2
OPEN
TRIPPED
CLOSED
BREAKER CONTROL
OPEN
CLOSE
MANUAL
AUTO
FEEDER BREAKER NO. 3
OPEN
TRIPPED
CLOSED
BREAKER CONTROL
OPEN
CLOSE
MANUAL
AUTO
FEEDER BREAKER NO. 4
OPEN
TRIPPED
BREAKER CONTROL
OPEN
CLOSE
MANUAL
AUTO
SATEC
282
283
P. 284
SATEC
122
0.984
120
SATEC
107
-.981
-105
SATEC
134
0.972
131

Logs went to a speadsheet

- Like the next page

Format Tools Data Window Help

Type a question for help

Arial 10

StringTime

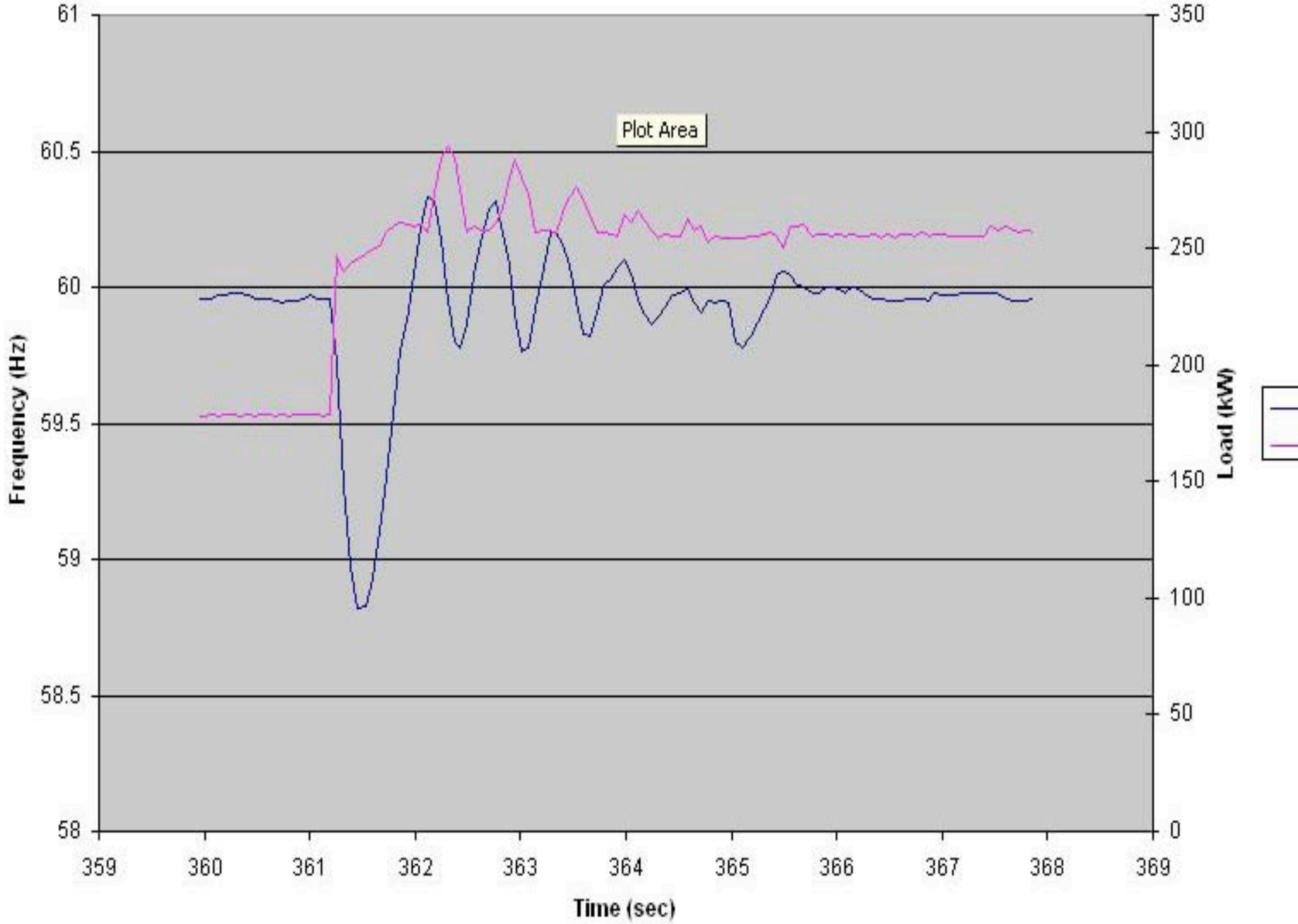
C	D	E	F	G	H	I	J	K	L	M	N	O
equence	kW	FREQ	kvar	V12	V23	V31	Vavg				F dev	% V dev
10754	177	59.97	56	489	487	492	489.3333				-0.03	1.944444
10755	173	59.96	56	489	487	492	489.3333				-0.04	1.944444
10756	174	59.94	54	490	485	492	489				-0.06	1.875
10757	176	59.94	53	490	486	491	489				-0.06	1.875
10758	174	59.96	54	490	486	492	489.3333				-0.04	1.944444
10759	178	59.96	54	489	486	491	488.6667				-0.04	1.805556
10760	177	59.95	53	490	486	491	489				-0.05	1.875
10761	178	59.97	54	490	486	491	489				-0.03	1.875
10762	176	59.97	54	489	486	491	488.6667				-0.03	1.805556
10763	178	59.95	54	489	486	491	488.6667				-0.05	1.805556
10764	179	59.93	55	489	486	491	488.6667				-0.07	1.805556
10765	179	59.95	57	490	486	492	489.3333				-0.05	1.944444
10766	181	59.98	54	490	487	491	489.3333				-0.02	1.944444
10767	182	59.94	54	490	486	491	489				-0.06	1.875
10768	187	59.98	52	490	487	491	489.3333				-0.02	1.944444
10769	187	59.95	52	490	487	491	489.3333				-0.05	1.944444
10770	187	59.99	53	491	488	491	490				-0.01	2.083333
10771	185	59.95	54	490	487	491	489.3333				-0.05	1.944444
10772	188	59.97	54	490	488	491	489.6667				-0.03	2.013889
10773	188	59.98	54	490	488	491	489.6667				-0.02	2.013889
10774	190	59.96	56	490	488	491	489.6667				-0.04	2.013889
10775	184	59.94	56	490	487	491	489.3333				-0.06	1.944444
10776	190	59.95	55	490	488	491	489.6667				-0.05	2.013889
10777	185	59.92	57	490	488	491	489.6667				-0.08	2.013889
10778	183	59.93	57	490	488	491	489.6667				-0.07	2.013889
10779	183	59.92	57	490	488	491	489.6667				-0.08	2.013889
10780	183	59.98	57	490	488	491	489.6667				-0.02	2.013889
10781	185	59.98	58	490	488	492	490				-0.02	2.083333
10782	184	60.03	57	490	488	491	489.6667				0.03	2.013889
10783	188	59.93	52	490	488	490	489.3333				-0.07	1.944444
10784	185	59.98	53	491	488	491	490				-0.02	2.083333
10785	188	59.92	51	490	488	490	489.3333				-0.08	1.944444
10786	190	59.97	50	490	488	491	489.6667				-0.03	2.013889

Data / 7Jul06 / 13Jul06 / 14Jul06 / 17Jul06

This is a famous graph derived for the tabular data

- The graph clearly shows that as the system slowed down from too much power, the diesel was loading up to compensate

- SO THE DIESEL WAS NOT THE SOURCE OF THE INSTABILITY


Plot Area
Frequency (Hz)
Load (kW)
Time (sec)
61
60.5
60
59.5
59
58.5
58
350
300
250
200
150
100
50
0
359
360
361
362
363
364
365
366
367
368
369