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MODIFIED INDUCTION GENERATOR

■ **Abstract:**

Wind energy occupies an important part in producing electrical energy all over the world, we are habituated to use Synchronous Generator -winded rotor or permanent magnetic-, induction Generator –squirrel cage or double fed[1]. In this paper on propose to use two machines running by one shaft, with different numbers of poles. The induction machine as main generator (high power) and a small synchronous generator as pilot one by this system we can generate electrical power from wind at all wind speeds.

■ **Keywords:**

Wind energy, induction machine, main generator

■ **INTRODUCTION**

In wind turbine we can use Induction Generator as main source and Synchronous Generator as exciter (small power). If the two machines have the same number of poles, we can find away to turn the I-G faster than the S-G, so in the beginning of operation, at low wind speed, the S-G- will give us certain voltage depending on rotating speed and excitation current.

This voltage will be applied on the terminals of I-G fig (1) so the squirrel cage I-G can work as a generator since it turn faster than S-G then by increasing the wind speed all parameters (voltage, frequency) will increase and the I-G will feed our external loads and we can inject the generated power in the grid[2].

In our laboratories by using a proto type model, small machines (Ind. &Syn.) which have the same number of poles. We did the test and prove that the I.G. can work as generators at all speed far from synchronous speed; the efficiency for our models is low. But we hope to modify it by using machines winded specially for this purpose.

■ **THE PRINCIPLE OF MODIFIED GENERATOR**

The modified induction Generator is consist of connecting the terminals of I-G to the output terminal of small pilot Synchronous Generator (permanent or winded rotor), and to run the two machines by one motor (wind power).

The number of pair poles of the two machines is equal we can use gearbox to create variable speed differences between the two machines. And if the Generators have different number of poles, then we can turn them on by the same shaft, at the same speed, but the differences in poles number must be determined for the best differences speed which gives the maximum power.
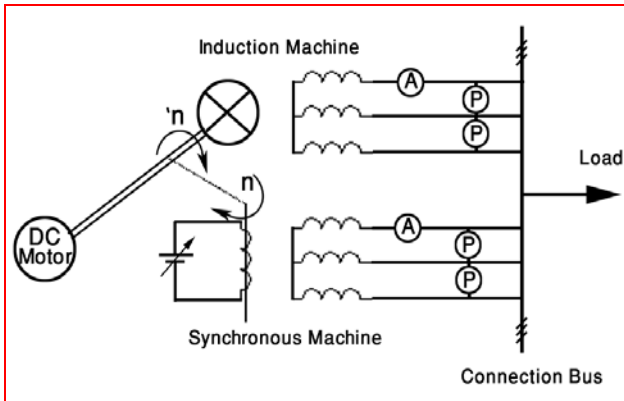
Figure1: Symbolic diagram
for Modified Induction Generator

To do that in the laboratory, we connect four poles induction motor with four poles synchronous generator on the same shaft of DC machine (as wind turbine). By using mechanical speed converter, we were able to run synchronous generator in a speed, which is relatively less than the speed of the induction motor, and we start running this group by a specified speed. Whatever it was, less than the synchronous speed which is related to 50 Hz. The synchronous generator will generate alternating voltage but at low frequency.

For this reason, we have connected the induction machine to this output (low frequency). In this case, the synchronous speed of the induction motor is the same speed of low frequency. So the induction motor works as a generator and begin to gives power to the net. When the speed comes faster, the frequency and the power come higher.

Synchronous generator in this modified machine is a virtual net. It distracts induction generator.

■ **The Modified Induction Generator Tests**

A- Laboratory machines parameters:
Machine 1: DC machine (substitute of wind turbine)
$Pn = 1.25$ [Kw]; $Ra = 2.9$ [Ω]; $Rf = 157$ [Ω];
$La = 0.13$ [H]; $J = 0.063$ [kg.m2]
Machine 2: Squirrel cage induction motor (suggested induction generator)
$P = 2.2$ [Kw]; $N = 1425$ [r.p.m];
$Un = 220/380$ [V]; $In = 9.6 / 5.5$ [A]
$Fn = 50$ [Hz]; $Cos\varphi n = 0.77$; $Rst = 2.7$ [Ω];
$Lst = 63$ [mH]; $J=0.02$[kg.m2]
Machine 3: Synchronous machine (suggested virtual source):

$N = 155$ [r.p.m]; Star $Un = 220$ [V]
                           $In = 3.2$ [A]
             Delta $Un = 127$ [V]
                     $In = 5.5$ [A]
$Uex = 220$ [V]; $Iex = 1.2$ [A];
$Sn = 1.2$ [KVA]; $P.F = 0.8$;
$Rst = 1.35$ [Ω]; $Rf = 127$ [Ω];
$Lst = 0.0102$ [H]

B-Laboratory tests on modified induction generator:
Using laboratory machines, and tiring to keep a constant speed differences between the I-G S-G and regulating the output voltage by changing the excitation current of Sy-G- and load we have obtain the result mentioned in table (1)
Where:
Nsyn: Synchronous Machine Speed
If: Synchronous Machine Exciting Current
Unet: Connection Bus Voltage
Isyn: Synchronous Machine output Current
Psyn: Synchronous Machine output Active Power
Qsyn: Synchronous Machine output Reactive Power
Ssyn: Synchronous Machine output Power
F: Connection Bus frequency
Iind   Induction Machine output Current
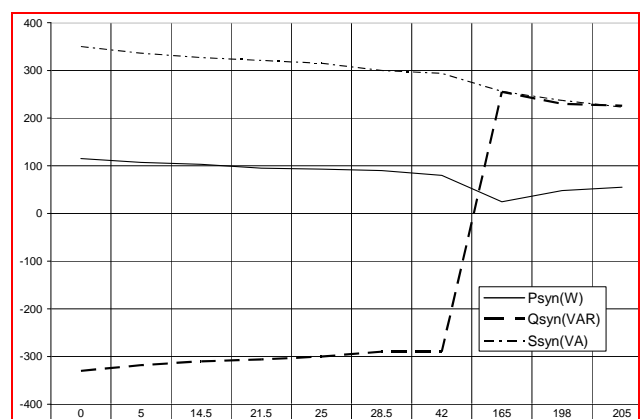Pind: Induction Machine output Active Power
Qind: Induction Machine output Reactive Power
Sind: Induction Machine output Power
Nind: Induction Machine Speed
Iload: Load current

From the laboratory results, we draw the active and reactive power for the synchronous generator as a function of load power changing (Pload) (Figure2).

	0	5	14,5	21,5	25	28,5	42	165	198	205
Psyn (W)	115	107	103	95	93	90	80	24,5	48	55,2
Qsyn (VAR)	-330	-318	-310	-306	-300	-290	-290	255	230	226
Ssyn (VA)	350	336	327	321	315	300	294	256	237	223

Figure2: Psyn, Qsyn and Ssyn as function to Pload

Table1: Laboratory test results

Nsyn (r.p.m)	670	670	670	670	670	670	670	670	670	670
If (A)	1.2	1.2	1.18	1.18	1.2	1.2	1.2	1.2	1.2	1.2
U net (V)	50	50	50	50	50	50	50	50	50	50
I syn (A)	6.9	6.72	6.57	6.4	6.3	6.2	6	5.1	4.7	4.6
P syn (W)	115	107	103	95	93	90	80	24.5	48	55.2
Q syn (VAR)	-330	-318	-310	-306	-300	-290	-290	255	230	226
S syn (VA)	350	336	327	321	315	300	294	256	237	223
F (Hz)	23	23	23	23	23	23	23	23	23	23
Iind (A)	7	7.03	7	7	7	7	7	7.63	7.9	7.9
Pind (w)	111	110	105	105	104	104	101	126	120	118
Qind (VAR)	-334	-335	-355	-335	-336	-334	-340	-374	-384	382
Sind (VA)	350	325	351	351	351	350	350	392	400	400
Nind (r.p.m)	750	750	750	750	750	750	750	750	750	750
I load (A)	0	0.1	0.29	0.43	0.5	0.57	0.84	3.3	3.95	4.1
P load (W)	0	5	14.5	21.5	25	28.5	42	165	197.5	205
Idcm (A)	3.2	3.2	3.7	3.8	3.8	3.8	4	5.4	5.8	5.9
U dcm (V)	170	170	170	170	170	170	170	172	175	175
P dcm (w)	544	544	629	646	646	646	680	928.8	1015	1032

Pload: load Active Power
Idcm: Prime mover machine Current
(Dc Machine Current)
Ucm: Prime mover machine Voltage
(Dc Machine Voltage)
Pdcm: Prime mover machine Power (Dc Machine Power)

As we see, the synchronous generator active power decrease at the end of chart when the active load get on, we also see, DC motor has consumed extra power from the net at these values.

In addition, the reactive power for synchronous generator changed also the synchronous generator current decrease in this stage, with constant output voltage.

In the entire situation, on notice that the applied frequency was 23 Hz and the voltage of the virtual net was 50V. That is mean, induction motor changed to work as induction generator at different frequency from nominal frequency (50Hz).
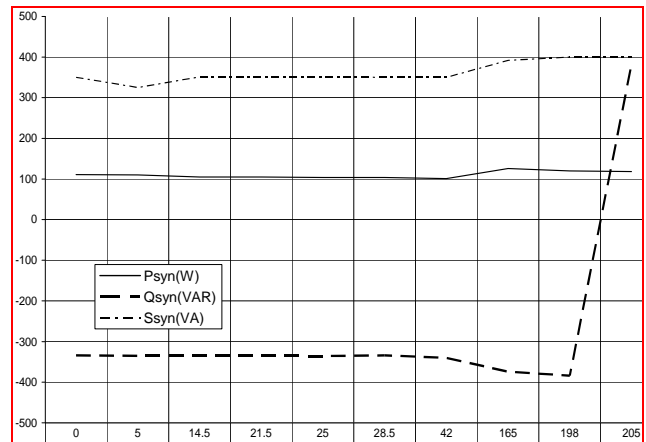
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Psyn (W)	111	110	105	105	104	104	101	126	120	118
Qsyn (VAR)	-334	-335	-335	-335	-336	-334	-340	-374	-384	382
Ssyn (VA)	350	325	351	351	351	350	350	392	400	400

Figure3: Pind, Qind and Sind as function to Pload

This test and other tests, which were repeated, assure that induction motor works as induction generator at any voltage and frequency.

But we should mention her, that the working conditions to run two machines are not easy, because the stator of induction motor supplied from low frequency /23Hz/and 50 voltage. And this is not convenient with the machine's impedance and features (it works at 220 voltage and 50H frequency). For this reason, the current consumed was very high (7A).

We did many tests on modified induction generator and we will mention some of it:

- Changing the speed of the synchronous generator with constant induction generator speed: and we have found at 100 r.p.m

Differential speed between the I.G. and S.G. and at many speeds (different working frequency) the output power of synchronous machine was maximum.

- changing differential speed between the two machines and constant voltage with same load:

We have noticed, the generated power increased with speed increasing.

■ SIMULATION OF MODIFIED INDUCTION GENERATOR WHICH IS CONNECTED TO THE NET

We simulate the modified induction generator by matlab program using real parameters for our laboratory machines:

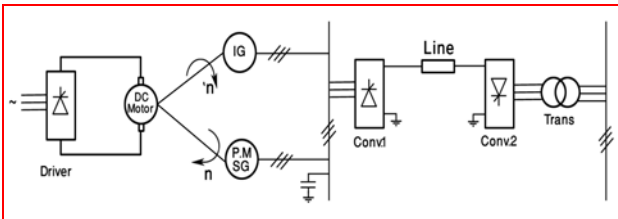We rely on libraries and the object of matlab program during the simulation [3].
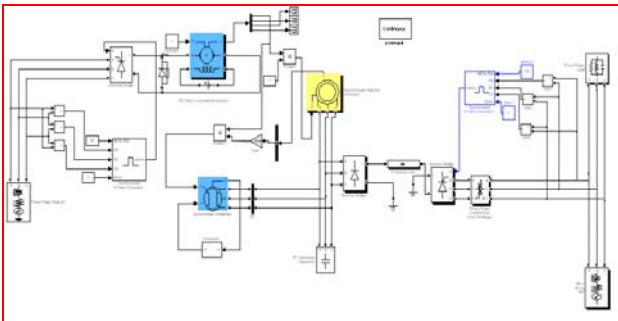

Figure4: symbolic diagram for simulated system

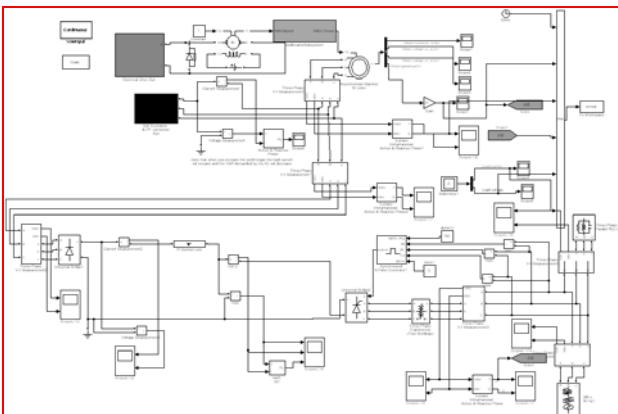Figure5: General diagram for matlab simulated system

Figure6: Specification diagram for matlab simulated system

The system has made from these components:

1- Squirrel cage induction machine.

2- Permanent magnetic synchronous machine.

3-Direct current machine: the prime mover (Wind turbine)

4-Converter Bridge to drive the DC machine (Wind turbine)

5- Transition line by DC current (over head line) with (Converter_ Inverter_ Duel converter)
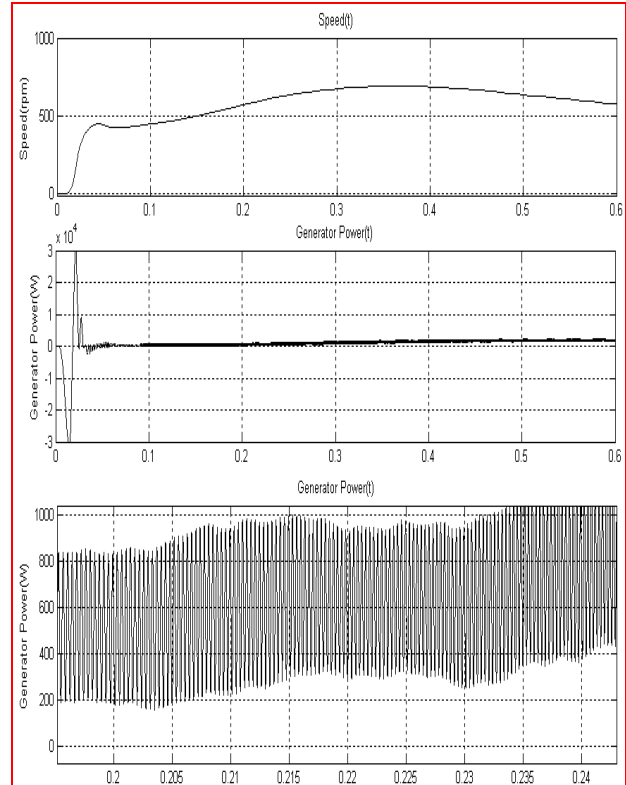
6- Transformer.

Figure7: Simulation result for modified induction generator at n=750 [r.p.m] [speed (t); Generator power (t)]
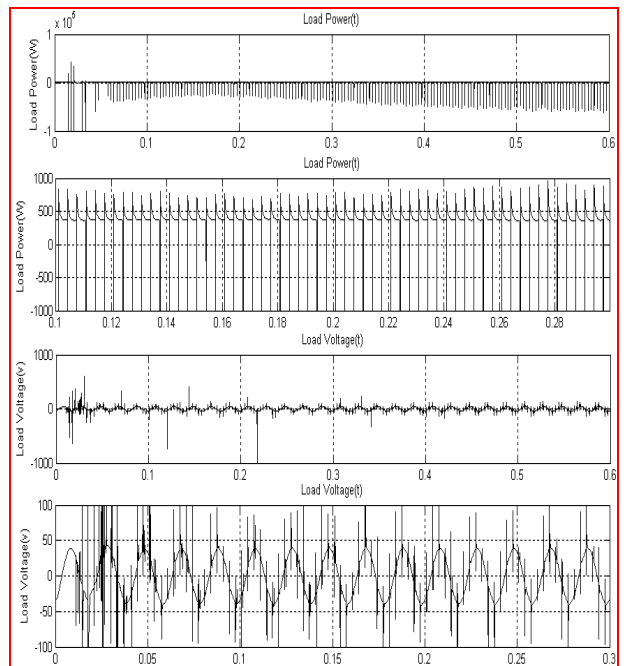

Figure8: Simulation result for modified induction generator at n=750 [r.p.m] [Load Power (t); Load Voltage (t)]

■ GENERAL RESULTS

The idea of induction generator comes from the need for induction generator speed over than the synchronous speed to start work as induction generator.

And by adding capacities to the stator of the induction generator, have a big effect to decrease the speed to start generating.

But generators need high capacities, with mechanical regulator to increase the speed of rotating the cost of gear box in wind turbine reach for 1/3 from the general costs.

So we have an idea to create a virtual network from the output of synchronous generator which illusion the induction motor which is connected with it.

And as long as synchronous generator could generate on alternative voltage in any rotating speed so by using any generator kind on the axis might help to create virtual network.

And as a result we connected a group of DC machines synchronous and induction to the same axis.

The system was started from zero, and the stator wind of induction machine connected on parallel with synchronous generator.

We have noticed that, the induction motor has started to inject power and generate it as long as we increase the speed as long as we could generate a bigger power. Finally, to reach the regular frequency for the network, we can use converter inverter system or dual converter in future as an output for the whole system [4]. It allows having any voltage or frequency in any speed, whatever was speed of wind, it can give the right frequency and voltage to the network

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