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DSP Based Performance Improvement for Horizontal Axis Wind Turbine Generator Model

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Abstract—This proposed system focus on monitoring and testing of Horizontal axis wind turbine generator model employing parallel computing technique, Multicore CPU and LabVIEW graphical programming language. By using parallel computing techniques the computing time is faster than the sequential approach. The wind turbine generator performance improvement can be done by using DSP multicore controller and by employing parallel computing technique. The method of real time testing is done by Hardware-in-the-loop simulation. The generator output is monitoring using LabVIEW graphical programming language.

Keywords- Horizontal axis wind turbine HAWT, Parallel computing, Lab VIEW, Digital Signal Processors DSP.

I. INTRODUCTION

Wind is simply air in motion. It is caused by the uneven heating of the Earth's surface by radiant energy from the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's energy at different rates. Water usually does not heat or cool as quickly as land because of its physical properties. An ideal situation for the formation of- local wind is an area where land and water meet. During the day, the air above the land heats up more quickly than the air above water. The warm air over the land expands, becomes less dense and rises. The heavier, denser cool air over the water flows in to take its place, creating wind. In the same way, the atmospheric winds that circle the Earth are created because the land near the equator is heated more by the sun than land near the North and South Poles. Today, people use wind energy to make electricity. Wind is called a renewable energy source

II. WIND TURBINE MODEL

A wind turbine is a rotating machine which converts the kinetic energy in wind into mechanical energy. If the mechanical energy is then converted to electricity, the machine is called a wind generator, wind turbine, wind power unit (WPU), wind energy converter (WEC).

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III. TYPES OF WIND TURBINE

There are two types of wind turbine they are
1. Horizontal axis wind turbine (HAWT)
2. Vertical axis wind turbine (VAWT)

Horizontal axis wind turbine

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator. Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount. Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since cyclic (that is repetitive) turbulence may lead to fatigue failures most HAWTs are upwind machines.

Vertical axis wind turbine

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable. VAWTs can utilize winds from varying directions. With a vertical axis, the generator and gearbox can be placed near the ground, so the tower doesn't need to support it, and it is more accessible for maintenance. Drawbacks are that some designs produce pulsating torque. Drag may be created when the blade rotates into the wind.

Advantage of Horizontal axis wind turbine

- Variable blade pitch, which gives the turbine blades the optimum angle of attack. Allowing the angle of attack to be remotely adjusted gives greater control, so the turbine collects the maximum amount of wind energy for the time of day and season.
- The tall tower base allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%.
- High efficiency, since the blades always moves perpendicularly to the wind, receiving power through the whole rotation. In contrast, all vertical axis wind turbines, and most proposed airborne wind turbine designs, involve various types of reciprocating actions, requiring airfoil surfaces to backtrack against the wind for part of the cycle. Back tracking against the wind leads to inherently lower efficiency.

IV. TYPES OF WIND TURBINE CONTROLLERS

1. Power control

A wind turbine is designed to produce a maximum of power at wide spectrum of wind speeds. The wind turbines have three modes of operation:

- Below rated wind speed operation
- Around rated wind speed operation
- Above rated wind speed operation

If the rated wind speed is exceeded the power has to be limited. There are various ways to achieve this.

2 Stall control

Stalling works by increasing the angle at which the relative wind strikes the blades (angle of attack), and it reduces the induced drag (drag associated with lift). Stalling is simple because it can be made to happen passively (it increases automatically when the winds speed up), but it increases the cross-section of the blade face-on to the wind, and thus the ordinary drag. A fully stalled turbine blade, when stopped, has the flat side of the blade facing directly into the wind. A fixed-speed HAWT inherently increases its angle of attack at higher wind speed as the blades speed up. A natural strategy, then, is to allow the blade to stall when the wind speed increases. This technique was successfully used on many early HAWTs.

3 Pitch control

Furling works by decreasing the angle of attack, which reduces the induced drag from the lift of the rotor, as well as the cross-section. One major problem in designing wind turbines is getting the blades to stall or furl quickly enough should a gust of wind cause sudden acceleration. A fully furled turbine blade, when stopped, has the edge of the blade facing into the wind. Standard modern turbines all pitch the blades in high winds. Since pitching requires acting against the torque on the blade, it requires some form of pitch angle control. Many turbines use hydraulic systems. These systems are usually spring loaded, so that if hydraulic power fails, the blades automatically furl. Other turbines use an electric servomotor for every rotor blade. They have a small battery-reserve in case of an electric-grid breakdown. Small wind turbines (under 50 kW) with variable-pitching generally use systems operated by centrifugal force, either by flyweights or geometric design, and employ no electric or hydraulic controls.

4. Yaw control

Modern large wind turbines are typically actively controlled to face the wind direction measured by a wind vane situated on the back of the nacelle. By minimizing the yaw angle (the misalignment between wind and turbine pointing direction), the power output is maximized and non-symmetrical loads minimized. However, since the wind direction varies quickly the turbine will not strictly follow the direction and will have a small yaw angle on average. The power output losses can simplified be approximated to fall with yaw angle.

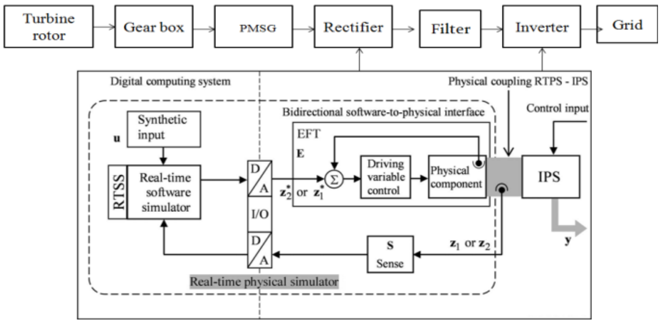
5. Electrical Braking

Braking of a small wind turbine can also be done by dumping energy from the generator into a resistor bank, converting the kinetic energy of the turbine rotation into heat. This method is useful if the kinetic load on the generator is suddenly reduced or is too small to keep the turbine speed within its allowed limit. Cyclically braking causes the blades to slow down, which increases the stalling effect, reducing the efficiency of the blades. This way, the turbine's rotation can be kept at a safe speed in faster winds while maintaining (nominal) power output. This method is usually not applied on large grid-connected wind turbines.

6. Mechanical braking

A mechanical drum brake or disk brake is used to hold the turbine at rest for maintenance. Such brakes are usually applied only after blade furling and electromagnetic braking have reduced the turbine speed, as the mechanical brakes would wear quickly if used to stop the turbine from full speed. There can also be a stick brake.

V. CONVENTIONAL BLOCK DIAGRAM



Drawbacks of Conventional System

- Poor Performance.
- Low Speed.
- High Computation time.
- High cost.

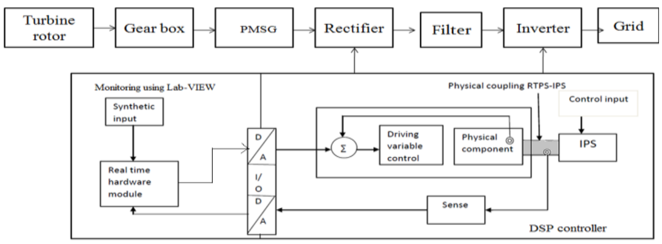
VI. PROPOSED SYSTEM

Special features of Proposed System

- Parallel computing technique.
- Parallel computing is classified into Multicore CPU and Multicore processor
- Pipelining concept makes the execution two times faster than sequential approach.
- Output in monitoring using Lab-VIEW.
- High performance.
- Provide concurrent execution.
- Use of non-local resources

The circuit diagram consists of following blocks Turbine rotor, gear box, PMSG, converters, filter, controllers and grid. Turbine rotor converts energy in moving air to rotary mechanical energy. A mechanical interface consisting of a step up gear and a suitable coupling transmits the rotary mechanical energy to an electrical generator by PMSG.

VII. PROPOSED BLOCK DIAGRAM



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VIII. PARALLEL COMPUTING

Parallel computing is a form of computation in which many calculations are carried out simultaneously, operating on the principle that large problems can often be divided into smaller ones, which are then solved concurrently. There are several different forms of parallel computing bit level, instruction level, data level and task level parallelism.

Elements of a Parallel Computer

1) Hardware

a) Multiple Processors
b) Multiple Memories
c) Interconnection Network

2) System Software

a) Parallel Operating System
b) Programming Constructs to Express Concurrency

3) Application Software

a) Parallel Algorithms

Parallel Computing Platform

a) Logical Organization

The user's view of the machine as it is being presented via its system software.

b) Physical Organization

The actual hardware architecture, Interconnection Networks (ICNs)-Provide processor-to-processor & processor to memory connections. Networks are classified as Static and Dynamic.

IX. NEED OF MULTI-CORE

• Difficult to make single-core clock frequencies even higher
• Deeply pipelined circuits:
– Heat problems
– Speed of light problems
– Difficult design and verification
– Large design teams necessary
– Server farms need expensive air-conditioning
• Many new applications are multithreaded.
• General trend in computer architecture (shift towards more parallelism)
• Parallelism at the machine-instruction level.
• The processor can re-order, pipeline instructions, split them into microinstructions, do aggressive branch prediction, etc.
• Thread-level parallelism (TLP).
• This is parallelism on a coarser scale.
• Server can serve each client in a separate thread (Web server, database server).
• A computer game can do AI, graphics, and physics in three separate threads.

Multiprocessors

Multiprocessor is any computer with several processors
• SIMD – Single instruction, multiple data
– Modern graphics cards
• MIMD– Multiple instructions, multiple data

Multiprocessor memory types

Shared memory:

In this model, there is one (large) common shared memory for all processors

Distributed memory:

In this model, each processor has its own. (small) local memory, and its content is not replicated anywhere else.

The real-time controller contains an industrial processor that reliably and deterministically executes Lab VIEW Real-Time applications and offers multi rate control, execution tracing, onboard data logging, and communication with peripherals. Additional options include redundant 9 to 30 VDC supply inputs, a real-time clock, hardware watchdog timers, dual Ethernet ports, up to 2 GB of data storage, and built-in USB and RS232.

X. SPECIAL FEATURES OF DSP PROCESSOR

• TMS320F2812 Digital Signal Processor
• 150 MIPS operating speed
• 18K words on-chip RAM
• 128K words on-chip Flash memory
• 64K words off-chip SRAM memory
• 30 MHz clock
• 2 Expansion Connectors (analog, I/O)
• Onboard IEEE 1149.1 JTAG Controller
• 5-volt only operation with supplied AC adapter
• TI F28xx Code Composer Studio tools driver
• On board IEEE 1149.1 JTAG emulation connector

XI. MONITORING PARAMETERS

• Power
• Rotor speed
• Pitch angle
• Efficiency

XII. DESIGN AND DEVELOPMENT TOOLS WHAT IS A DIGITAL SIGNAL CONTROLLER?

The TMS320F2812 belongs to a group of devices that are called "Digital Signal Controller (DSC)". In computing, we use words like "Microprocessor", "Microcomputer" or "Microcontroller" to specify a given sort of electronic device. When it comes to digital signal processing, the preferred name is "Digital Signal Processors (DSP)".

A Digital Signal Processor

A Digital Signal Processor is a specific device that is designed around the typical mathematical operations to manipulate digital data that are measured by signal sensors. The objective is to process the data as quickly as possible to be able to generate an output stream of 'new' data in "real time".

B. Digital Signal Controller

Finally, a Digital Signal Controller (DSC) is a new type of microcontroller, where the processing power is delivered by a DSP – a single chip device combining both the computing power of a Digital Signal Processor and the embedded peripherals of a single chip computing system.

XIII. TMS320F2812 DSP CONTROLLER BLOCK DIAGRAM

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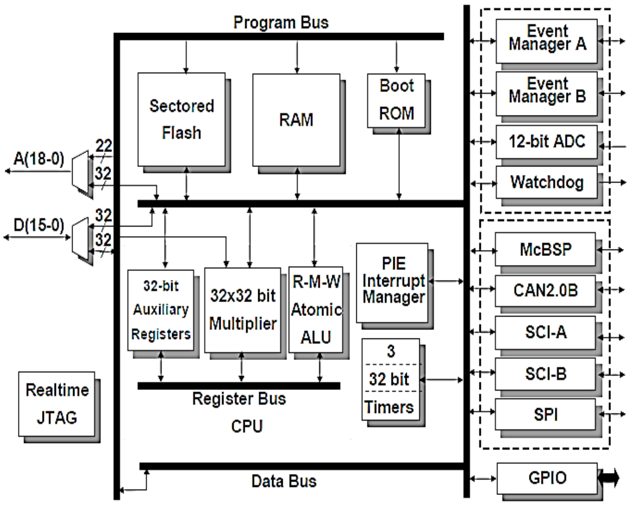
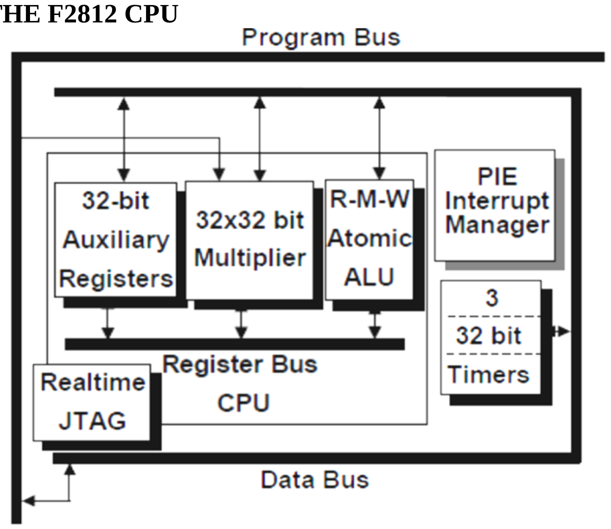


The TMS320F2812 Block Diagram can be divided into 4 functional blocks:

- Internal & External Bus System
- Central Processing Unit (CPU)
- Memory
- Peripherals

THE F2812 CPU



The F2812 –CPU is able to execute most of the instructions to perform register-to register operations and a range of instructions that are commonly used by micro controllers, e.g. byte packing and unpacking and bit manipulation in a single cycle. The architecture is also supported by powerful addressing modes, which allow the compiler as well as the assembly programmer to generate compact code that almost corresponds one-to-one with the C code. The F2812 is as efficient in DSP math tasks as it is in the system control tasks that are typically handled by microcontroller devices. This efficiency removes the need for a second processor in many systems.

SPECIAL FEATURES OF DSP CONTROLLER

- TMS320F2812 Digital Signal Processor
- 150 MIPS operating speed & 30 MHz. clock
- 18K words on-chip RAM &128K words on-chip Flash memory
- 64K words off-chip SRAM memory
- 2 Expansion Connectors (analog, I/O)
- Onboard IEEE 1149.1 JTAG Controller
- 5-volt only operation with supplied AC adapter
- TI F28xx Code Composer Studio tools driver
  - On board IEEE 1149.1 JTAG emulation connector

Code Composer Studio IDE

Code Composer Studio is the environment for project development and for all tools needed to build an application for the F28X -Family.

The basic steps are: edit, compile and link, which are combined into "build", then debug. If you are familiar with other Integrated Design Environments for the PC such as Microsoft's Visual Studio, you will easily recognize the typical steps used in a project design. If not, you will have to spend a little more time to practice with the basic tools shown on this slide. The major difference to a PC design toolbox is shown on the right-hand side – the connections to real-time hardware.

Step-by-step approach:

Step 1: Open Code Composer Studio

Step 2: Create a F28x – Project, based on C

Step3: Compile, Link, Download and Debug this test program

Step 4: Watch Variables

Step 5: Real time run versus single-step test

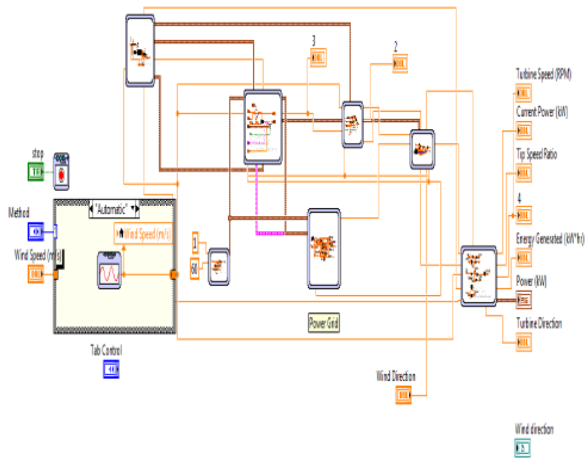
Step 6: Use Breakpoints and Probe Points

Step 7: Look into essential parts of the DSP during Debug

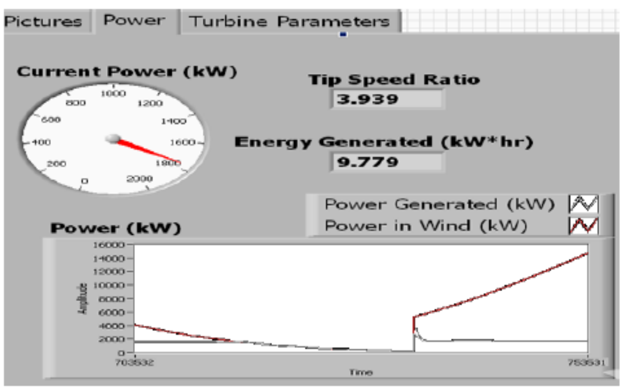
ADVANTAGES OF PROPOSED SYSTEM

- Renewable source of energy.
- Economically efficient and Eco-friendly.
- Real-time latency.
- Field test carried in laboratory.
- Easily adapt to environment.

SIMULATION BLOCK DIAGRAM



POWER OUTPUT



TURBINE PARAMETERS OUTPUT

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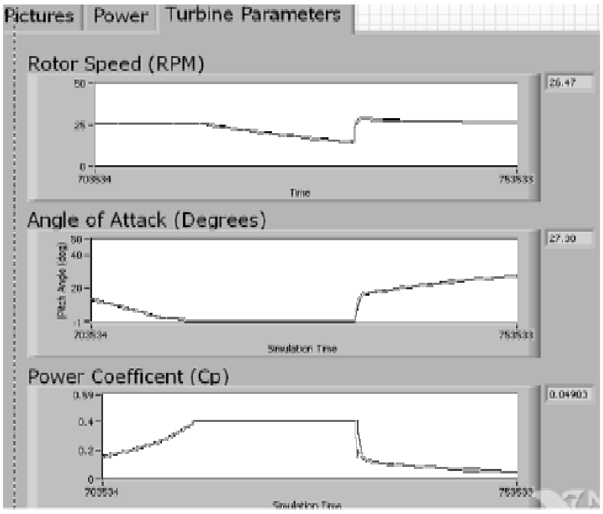

CONCLUSION

In this model, performance improvement for variable speed Horizontal axis wind turbine generator is present. This is achieved by parallel computing technique, multicore CPU and Lab VIEW graphical programming language. The wind turbine parameters such as output power, rotor speed, pitch angle and co-efficiency are monitoring by Lab VIEW graphical programming language. By employing DSP multi core processor the real time testing of wind turbine generator is done with low-cost.

The source signal and reference signal is compared and PWM output signal is generator by code composer studio and simulation output is done by Lab VIEW in Phase I. The DSP based performance improvement for wind turbine generator hardware module is done in Phase II.

FUTURE SCOPE

Performance improvement is currently an active topic for research in the areas of wind turbine generator. By using application of parallel computing technique, improving the computing time compare with traditional computing method. Taking of the pipelining technique, code runs two times faster than in a sequential approach. The generating power, efficiency, tip speed ratio, rotor speed are improved by this techniques. The new signatures that will be studied are defined as parallel computing technique, this techniques is implemented to wind turbine generator with low-cost, safety in industrial real time testing.

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