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Use of parallel processing in applications for hydro power scheduling – current status and future challenges

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Abstract

This paper gives an overview of models for hydro power scheduling and market simulation developed at SINTEF Energy Research. All of the models are in operative use by power producers, transmission system operators, consultants and regulators operating in the Nordic power market. Several of the models have been adapted to use of parallel processing to decrease computation time. The paper gives an overview of existing models where parallel processing has been applied.
Finally future challenges and the need for higher level of parallelization are discussed and exemplified by two new models for power market simulation that use two level parallelization. Both of these models have the potential for efficient utilization of hundreds or even thousands of processors (or cores) and can be run on large compute clusters.

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1. Introduction

Operation of hydro systems involves a range of different tasks. Power producers have to find the optimal use of hydro resources and manage the economic risk of operation. Power producers and transmission owners perform system analyses and plan system expansion, refurbishment and other investments and plan for maintenance. All these tasks require decision tools for scheduling of hydro resources.

Hydro-thermal scheduling is a very complex task where the purpose is to find the optimal use of the available resources over a given study period. In purely thermal systems the scheduling problem is primarily decoupled in

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time and each generating unit have a direct operating cost and this cost does not depend on the costs of other plants. In hydro-thermal systems, particularly when the reservoirs have significant storage capacity, the problem becomes coupled in time. The hydro plants can use the "free" energy stored in the reservoirs to meet demand thereby avoiding the cost of using thermal units. The hydro resource is however limited by the storage capacity of the reservoirs and inflow, and this introduces a time dependency in operating costs. It can either be used today to reduce current operating costs by reducing use of thermal units today, or stored for use at later stages to reduce future operating costs. Thus the water resource, although having no direct costs, has an indirect opportunity cost, also called water value (WV). The operating decision for hydro power is to produce today or store for future use.

There are several future uncertainties that will have influence on the operation of the hydro system. Especially the future inflow is important for the operation of the hydro system, but also uncertain parameters like temperature, fuel prices and supply of other energy sources may have a large impact.

In addition to the dynamic and stochastic nature of the hydro-thermal system the problem may be even more complex due to factors such as losses, transmission limitations, start-up costs of thermal as well as hydro plants, ramping rates of plants and transmission, topology and time delays. All this make the decision problem a very complex and time consuming task to solve.

This paper gives an overview of computer applications for hydro-thermal scheduling and power market simulation developed at SINTEF Energy Research. All applications are in use by commercial market actors in the Nordic power market. The paper will also present some details on how parallelization has been introduced and further present some experience and thoughts on future development using multilevel parallelization.

2. Parallel processing

Traditionally, software has been written for serial computations. The problem is broken into discrete series of instructions which are executed sequentially one instruction at a time on a single processor as illustrated in Fig. 1. a)

Almost all new computers and all servers are parallel from a hardware perspective. Currently most CPU's have multiple execution units or cores and servers have multiple CPU's installed. Also other hardware technologies, e.g. internal memory and intercommunication allow parallel access. Servers can also be set up to communicate on a local network in parallel compute clusters.

If a given problem can be broken into separate parts which can be solved independently, this problem can be solved by using parallel computing to speed up calculations. Each part is broken into series of instructions, and the instructions for a part are executed on a given processor/core as is illustrated in Fig. 1 b).

There are several models for parallel programming in common use, for example threads using shared memory and distributed memory using message passing. Distributed memory and message passing is typically a manually developed parallel code, while threads and shared memory can be either automatically, imbedded in the compiler, or manual using e.g. OpenMP. This is an industry standard available on many platforms and programming languages.

In computer code presented in this paper, message passing is primarily applied using a standardized and portable message passing system called Message Passing Interface (MPI) [1]. This standard supports both point-to-point and collective communication between concurrent processes and is one of the most used models for high-performance computing today. Point-to-point communication is used to send messages between individual processes. Typically in applications described in this paper this is applied to communicate between a master process and a slave process. The master process is a process dedicated to administrate the parallel computations while slave processes are dedicated to solve different parts of the calculations. Collective communication is used to send data from the master process to all the slave processes, sending results from all slave processes to the master process or sending data from all processes to all other processes.

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