Remote demonstration of the GOLEM tokamak

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Abstract—The GOLEM tokamak serves as an educational device in the field of tokamak physics, technology, diagnostics and operation in the scope of the wider field of thermonuclear fusion. The typical scenario of a remote demonstration of the GOLEM tokamak is described. The new remote control and live status web interface in its mobile-ready form is presented.

Index Terms—Tokamak technology and control, online experimentation, remote participation, education

I. INTRODUCTION

The GOLEM tokamak [1], a.k.a. the grandfather of all tokamaks [2], currently serves as an educational device at the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague (FNSPE, CTU) with the aim of training domestic as well as foreign students and young physicists in the field of tokamak physics, technology, diagnostics and operation in the scope of the wider field of thermonuclear fusion.

One of the ways in which its educational mission is fulfilled are remote demonstrations during various training courses, winter or summer plasma physics and technology events.

The aim of such a remote demonstration is to provide participants (typically students) with a reasonable understanding of the relationship between the achieved plasma quantities and the adjustable technological parameters of such a complex device. This is often accompanied by a competition among participants to achieve the longest discharge duration or the highest plasma current or the highest electron temperature.

II. TYPICAL REMOTE DEMONSTRATION SCENARIO

A typical remote demonstration lasting $\sim$2 hours for an audience consisting mostly of non-experts or lay people is described here. With a repetition rate of $\sim$1 discharge per 2 minutes, nearly all (active) participants typically have a chance to configure their own discharge during the demonstration.

Such a remote demonstration event is lead by a qualified "performer", typically a researcher or a teacher from the GOLEM tokamak staff or a trained PhD student. The

remote performer typically communicates with an operator on the tokamak side through a video conference or text chat technology (whichever is available or most convenient).

The demonstration usually starts by a short presentation by the performer, during which the motivation of achieving thermonuclear fusion in a tokamak is introduced, then the tokamak technology is briefly described sub-system by sub-system. Each sub-system is illustrated by an engineering schematic and labelled pictures of the system as seen at the GOLEM tokamak. A sufficiently qualified performer may even demonstrate the activation of some of these sub-systems during the presentation, e.g. initiate the vacuum pump-down.

Then the performer explains step-by-step the discharge procedure how the steps relate to the adjustable parameters in the remote control interface. Finally, the performer displays a QR code page which participants can scan with their mobile phones and access the remote control interface themselves. The performer then shows the participants how to configure a real discharge request and then submits it. He then guides the participants through the live real-time view of the experiment status during the execution of the configured discharge request. Afterwards the participants can submit their requests and watch as they are processed through the live status view.

The whole system is essentially offered free of charge. The only "fee" is that the remote participants send a postcard from the venue of the remote operation.

III. REMOTE CONTROL INTERFACE

While the GOLEM tokamak has for long been known to have remote operation capabilities [3], [4], the recently developed new virtual remote control interface offers a better experience for such remote demonstrations. Specifically, the new virtual control room interface a) offers a wizard-like experience in order to better explain the necessary steps to students and prevent the omission of an important setup step, b) improves cross-browser and cross-platform compatibility in order to enable a operation by a wider audience (including mobile-phone or tablet users). The new live real-time overview of the experiment aimed to add up-to date information on the machine status to the existing IP camera views.

The new web application is built with modern (but tested and reliable), cross-browser-compatible, responsive technologies such as JQuery, Bootstrap in the frontend and the Flask micro-framework running on the Apache-WSGI backend server. The responsive design of the web application enables even mobile (smart-)phone users (the majority during remote

demonstrations) to easily participate, the typical view on an iPhone screen is shown in Figure 1. Each of view is actually composed from 2 columns displayed side-by-side only on a wide, desktop-like display, but responsively stacked vertically on a narrow mobile-like display.

The system is protected with an access token provided by the operators for the particular event. For such remote demonstration events the access token gives access for typically 30 minutes and is typically encoded in the link represented by the QR code displayed for participants. Therefore, when the participants visit the control interface for the first time, a form is displayed asking only for the "Identification" which is a user-name by which the current user wishes his discharges to be identified in the database.

The remote control room interface shown in the left part of Figure 1 consists of 2 main panels. The first panel contains 6 tabs, each tab corresponds to a step in the discharge setup procedure configuring a given tokamak sub-system. The second panel contains a rendering of the 3D model which dynamically changes according to the currently selected tab.

Each tab contains brief information about the setup step, an engineering schematic of the tokamak sub-systems with the one currently being configured highlighted, slider and checkbox widgets for configuring discharge parameters, a "Next" button which switches to the next tab (configuration step) and a "Set recommended value" button. All the settable parameters are completely safe, therefore, participants can freely choose their parameters without any fear of destroying any part of the device.

The live real-time overview of the machine status in the right part of Figure 1 shows the experiment during the preparatory phase of the discharge. The gauges over the engineering scheme show the gradual charging of capacitors and filling of the chamber with the selected working gas. The wide-angle room camera shows the general surroundings of the device, while the chamber camera shows the pre-ionization filament activation inside the chamber. The queue of discharge requests with the most important basic parameters is also shown to give remote participants an idea of when their requests will be executed.

The chamber camera with a sampling rate of 1/30 s usually captures the flash of plasma (living only several tens of ms) at least on a portion of a frame. This moment gives the remote participants visual confirmation of plasma in near-real-time and is particularly popular during remote demonstrations.

IV. Summary

The remote demonstration of the GOLEM tokamak enables remote participants to gain basic understanding of tokamak technology and its use for achieving controlled thermonuclear fusion. The new remote control interface enables participants to easily use their mobile devices to control the tokamak. Readers interested in a remote demonstration at their venue are very welcome to exploit the system[1].

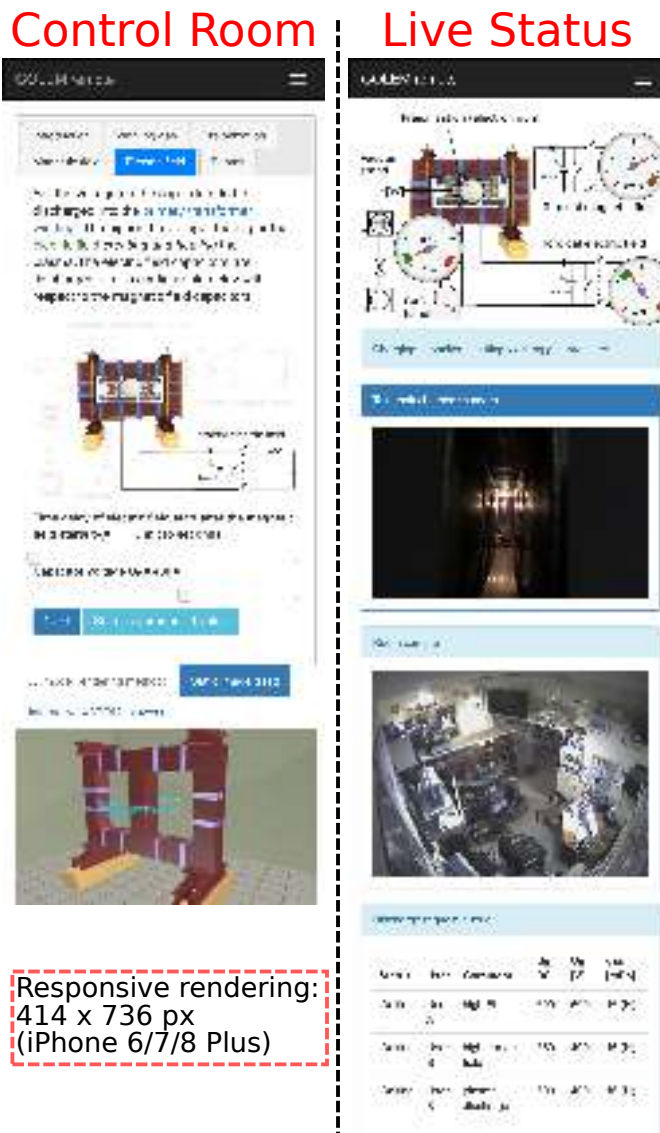
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Fig. 1. Remote control and live status interface of the GOLEM tokamak as viewed on a mobile smartphone. The control room interface at the electric field setup step is shown on the left. The live real-time view of the experiment during the preaparatory phase of the discharge is shown on the right.

References

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