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Saving Energy and Cost with application of Railway Smart Wayside Object Controllers

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Abstract

Trackside equipment and signalling devices are controlled by wayside object controllers (OC). Radio communication systems enable the wireless transmission of command control and signalling (CCS) data, which can help to reduce the cost of cabling and installation. However, for regional lines with low traffic volumes in rural areas, most of them are non-electrified, so a special cable for powering the wayside object controller system is still needed to be installed along the track, which would significantly increase the construction cost and maintenance work. A smart wayside object controller (SWOC) is suggested, which would be autonomous, self-sufficient, remotely-monitorized and locally-powered to ensure its proper operation, so the cabling and installation work can be totally removed. In order to demonstrate its viability and benefits over the existing systems, this work studies the possibility to use different renewable energy sources to power the system and then estimates the life cycle cost (LCC) of the SWOC in long-term operation. This study shows that in most places, it is sufficient to use 100% renewable energy sources to power the SWOC, trackside equipment and signalling devices. Compared with the existing system, the SWOC shows a significant cost saving in long-term operation by removing cabling and installation, reducing trackside maintenance and replacing the power supply with renewable energy power sources. Therefore, the SWOC shows its benefits over the existing system in both economical and environmental aspects. In the end, some suggestions on future development and implementation of SWOC are given.

Keywords: railway signalling system, wayside object controller, renewable energy, life cycle cost.

1 Introduction

In railway signalling systems, there are a considerable number of wayside objects installed along the tracks to ensure operation, e.g., optical signals, point machines of switches, and barrier gates and warnings on level crossings. The wayside objects are controlled and driven by wayside object controllers (OC), which are linked to interlocking and centralized traffic control (CTC) [1]. The wayside OCs are geographically dispersed either along railway lines or in stations. Traditionally, to control and power the OCs, fibre optics and copper cables are needed to be installed to link the OCs to the interlocking and the nearby power supply, so a great amount of work and cost is associated with cabling. For the modern European rail traffic management system (ERTMS), data and instructions are digitally transmitted via wireless radio networks, which can help to reduce the on-site cabling work along the track [2-3]. Nevertheless, long power cables have to be installed to connect to the electric power supply and cable ducts have to be built along the track. For electrified railway lines the electric power can be directly acquired from the catenary above the track, but for non-electrified regional lines there is still a significant amount of cabling work needed to link to the nearest stations or the public grid, which still results in costs in cabling and maintenance.

To minimize the construction and maintenance costs, a concept of smart wayside object controller (SWOC) is suggested, which would be autonomous, self-sufficient, remotely-monitorized and locally-powered [4]. The SWOC is supposed to be off-grid and powered by renewable energy sources (RES), e.g., solar energy, wind power and energy harvesting, which has been implemented in many applications [5]. The on-site power supply can, therefore, help to not only reduce the construction and operational costs but also make the railway more environmentally friendly. Firstly, the present work introduces methods to calculate the power and energy demands of the SWOC system, to look for RES to power the system, and to estimate the life cycle cost (LCC) of the SWOC in long-term operation. Secondly, based on the proposed methods, the work performs a case study, which shows the results and possible power supply solutions and compares the SWOC with the existing OC systems. In the end, the benefits of the SWOC systems are summarized, and some suggestions on future development are given.

2 Methods

In order to demonstrate the viability of the SWOC concept, this work firstly needs to study the configuration and dimensioning of different local RES and energy storage systems (ESS), which can provide sufficient power to operate the SWOC system. Figure 1 shows the method to study the configuration and dimensioning of the RES and ESS. Each SWOC is responsible for controlling several wayside objects and powering itself. The maximum power peak and total energy are calculated as indicated. Then the configuration of different local renewable energy sources can be checked against available renewable energy sources and climate conditions. Since most of the RES can neither provide a stable power supply (in a day or through a year) nor accommodate a high power peak, the energy storage system is used to balance the difference between the power supply and power demand. Eventually, the method can indicate the possibility of using the SWOC system at the location and suggest the system setup (i.e., the configuration of RES and volume of ESS). Since the railway system needs a reliable power supply, the boundary conditions of the SWOC system can be derived and a system back-up can therefore be calculated.

To reflect the benefits of the SWOC system over the existing systems, this work then proposes a method to estimate the LCC of the SWOC in long-term operation, as shown in Figure 2. The life cycle costs consist of three parts: initial (or capital) costs, recuring (or operating) costs, and disposal costs [6]. Regarding the initial costs, the big change between the SWOC system and the existing system is the removal of the installation of the long power cable from the remote electric power supply, so much civil work and cabling work can be avoided. Although the cabling work can be reduced, extra costs associated with the installation of local RES and ESS incur. Regarding the recurring costs, there are two parts: energy costs, which are saved because of the application of RES, and the maintenance costs, which are linked to regular inspections, service and replacements/repairments of some key components. Since the SWOC system is used for a long time, interest rate, inflation and disposal costs can be included and studied.

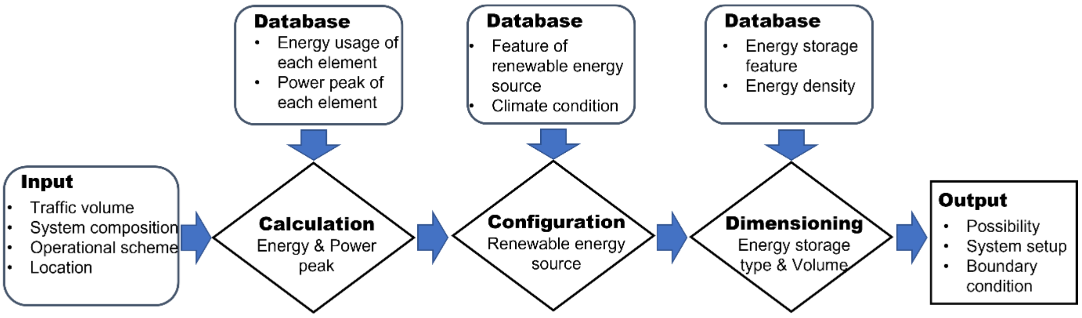

Figure 1: Flowchart of configuration of local renewable energy supply.

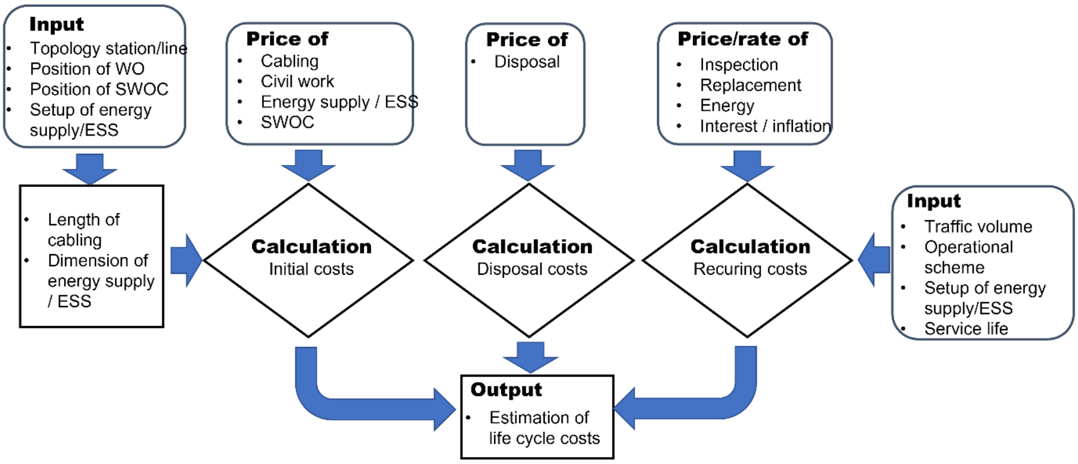

Figure 2: Flowchart of LCC analysis.

3 Results

This work takes Tortuna station in Sweden as an example to study the implementation of the SWOC system and also compare the energy usage and LCC of the SWOC system and the centralized OC system. Figure 3 shows the schematic layouts of the two systems. All the wayside objects are located at the two ends of the station with a spacing distance of 700 m. For the OC system, all the wayside objects are driven and linked to the OC in the middle via cables installed through the station, and an extra power cable is installed to get electric power from either the nearest station with electricity or the public grid. For the SWOC system, two SWOCs are separately installed at the two ends and each SWOC controls the wayside objects nearby. One of the two SWOCs works as master SWOC which is responsible for communication with both the CTC centre and the other SWOC (slave SWOC). Since the two SWOCs get power from the localRES, it is not necessary to install cables through the station.

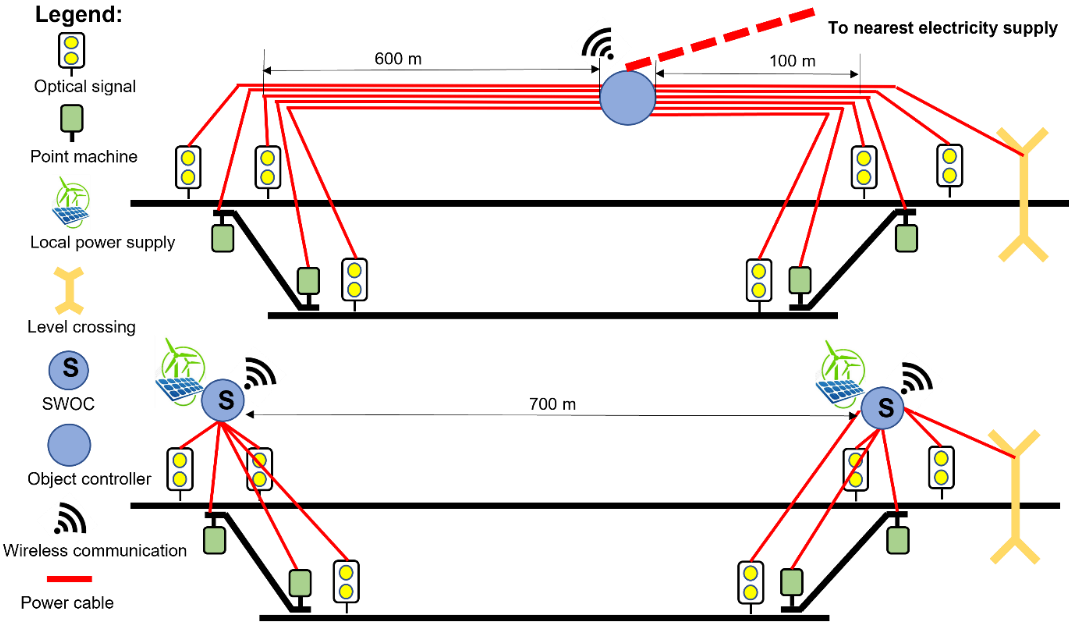

Figure 3: Comparison of layouts of OC and SWOC.

Firstly, it is necessary to find out the possible local RES which can provide sufficient energy to power the two SWOCs. The SWOC on the right has to drive three optical signals, two point machines and level-crossing barriers with warning lights. We assume that each day four trains pass through the station and meet two times in the morning and evening, respectively. Therefore, the energy demand can be calculated accordingly. The renewable energy supply changes with the wind, sunlight and season, so meteorological data near Tortuna station can help to calculate the renewable energy supply [7]. Figure 4 compares the renewable energy production and energy demand of SWOC in each month [8]. It shows that wind turbines can provide sufficient energy to the SWOC.

This work simplifies the LCC analysis, in which only the initial costs and recurring costs related to operation are considered. The initial costs include procurement of materials and equipment, construction and installation. The recurring costs consider maintenance work and energy usage. The LCCs of the SWOC system and the existing OC system can be estimated accordingly. Figure 5 compares the LCCs of the two systems [9].

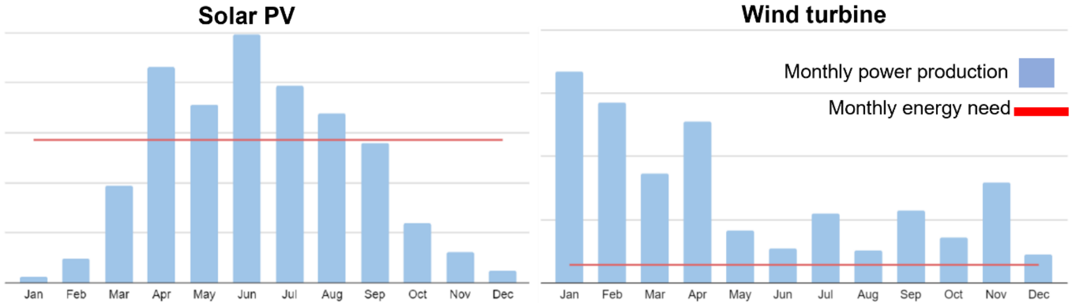

Figure 4: Comparison of renewable energy production and energy use of SWOC.

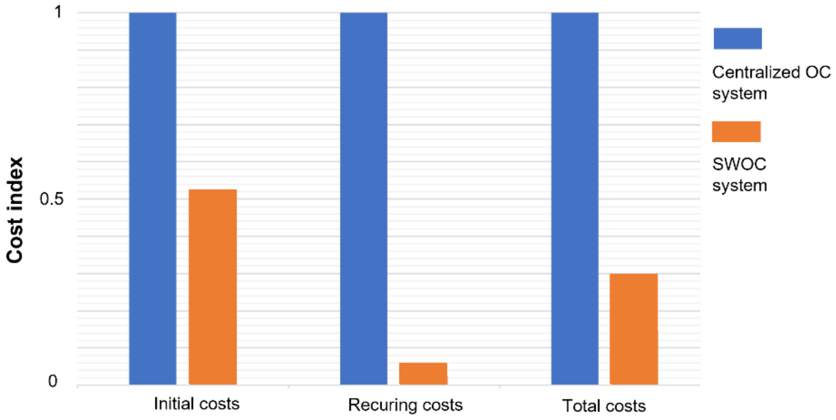

Figure 5: Comparison of LCCs of OC and SWOC.

4 Conclusions and Contributions

This work studied a concept of smart wayside object controller (SWOC) which is powered by a local RES and wirelessly communicates with the CTC centre and other SWOCs. To demonstrate the viability of the SWOC system, a method to calculate system energy demand and investigate a possible solution for a local RES. To further show the benefits of the SWOC system over the existing OC systems, this work developed a method to estimate the life cycle costs (LCC) of the SWOC in long-term operation. With help of the developed methods, this study performed a case study based on Tortuna station in Sweden to investigate the implementation of the SWOC system and to compare the SWOC system with the OC system. Through this work, the following conclusions can be drawn:

- It is possible to use 100% local RES to power the SWOC system. However, the RES should be carefully studied because the energy supply of RES is not stable and sometimes cannot meet the energy demand of the SWOC system.
- Compared with the OC system, the SWOC shows a significant cost saving in long-term operation because of removing cabling and installation, reducing

trackside maintenance and replacing the power supply with renewable energy power sources.

In addition, the SWOC system has more benefits over the OC system. The SWOC system is decentralized and not limited by the external electric power supply, which gives more flexibility in the implementation of the SWOC. This feature is quite beneficial for non-electrified railway lines in rural areas, where it is hard and costly to acquire an external electric power supply. The SWOC system also has a simple physical structure in the railway station, so the costs in construction and operation can be much reduced. From an environmental aspect, a 100% renewable energy driven SWOC system can make the railway sector even more eco-friendly and eventually contribute to the establishment of a carbon-neutral society in the future.

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